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HARDENING BY REHEATING AFTER COLD WORKING

By Marcus A. Grossmann and C. C. Snyder

Abstract

In this paper the authors wish to advance a theory which explains the phenomenon of the hardening of cold-worked steel by reheating at low temperatures. Attention is called to certain significant features observed under the microscope, and other evidence is offered pointing to a simple reason for the observed changes in strength, hardness and ductility.

Effects of reheating after quenching as well as cold working are discussed in detail, and their different natures set forth. The theory suggested has to do with a thin layer of "interblock" material, which increases gradually in thickness as the reheating temperature is raised, reaching a maximum effective thickness at approximately 600 degrees Fahr.

In his Howe Medal paper, Dr. F. C. Langenberg[1] gave far reaching fundamental data on increase in strength obtained in gun-tubes, when these were cold-worked and particularly when the cold work was followed by low-temperature reheating. The phenomena have been of great practical importance, and it was of interest to examine them further. Also, in a discussion of that paper, T. D. Lynch referred to wire whose tensile strength he had increased greatly by subjecting it to stretching in conjunction with a low-temperature reheating. The literature also contains numerous references to an increase in hardness and tensile strength, accompanied by a decrease in toughness which occurs

[1]F. C. Langenberg, Effect of Cold Working on the Strength of Hollow Cylinders, Transactions, American Society for Steel Treating, October, 1925, p. 447.

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. Of the authors, who are members of the society, M. A. Grossmann is metallurgist with the Central Alloy Steel Corp., Canton, Ohio, and C. C. Snyder is connected with the research department of the same company. Manuscript received July 18, 1927.

when bars which have been cold drawn are reheated to low temperatures. Thus S. C. Spalding[2] discusses in detail an increase in strength and Brinell hardness and a decrease in toughness when cold drawn bars have been reheated to low temperatures. Delbart[3] gives data on Charpy impact tests on steels that have been cold drawn and then reheated. Extensive data are also given by Goerens,[4] who in addition to the strength examined other properties. The phenomenon to be examined here is the increase in strength which is caused by the reheating of the cold-worked material. The cold working in itself brings about an increase in strength. This increase in strength (and hardness) due to cold working has already been a subject of considerable theoretical speculation in the literature. But if the cold-worked material is reheated to low temperatures there is an additional increase in strength above that exhibited by the material which has been cold-worked only. The increase in strength and loss in ductility is most pronounced when the reheating of the cold drawn material is done in the neighborhood of 600 degrees Fahr. (315 degrees Cent.).

There is another set of phenomena which may be considered in this connection. A loss of ductility and impact toughness is observed in hardened low-alloy steels, when these are reheated in a similar temperature range. Thus, Dr. J. A. Mathews[5] early called attention to a "brittle range" in which the toughness as measured by the Izod machine was materially lowered, when the hardened low-alloy steel was reheated to low temperatures. One of the present authors[6] advanced a tentative theory to account for this brittle range in the quenched hardened steels. In the cold-worked material, however, the phenomena have been somewhat obscure and so far as the authors are aware, a complete hypothesis for their explanation has so far been lacking. Thus Dr. Sauveur pointed out in his discussion of Dr. Langenberg's paper[7] that

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[2]S. C. Spalding, Effect of Reheating on Cold Drawn Bars, TRANSACTIONS, American Society for Steel Treating, May, 1926, p. 685.

[3]G. Delbart, Étude de la fragilité des aciers étirés a froid. *Comptes Rendus,* 1926, p. 131.

[4]P. Goerens, The Influence of Cold Working and Annealing on the Properties of Iron and Steel. Iron and Steel Institute, Carnegie Scholarship Memoirs, Vol. 3, 1911.

[5]J. A. Mathews, Year Book of the American Iron and Steel Institute, 1921, p. 147.

[6]M. A. Grossmann, Brittle Range in Low Alloy Steels, *Iron Age,* July 17, 1924.

[7]See foot note 1.

there was as yet no evidence pointing to a definite reason for the phenomena. It had even been suspected that the two sets of phenomena (in cold-worked and in quenched materials) might have a similar origin but Archer[8] pointed out that the evidence did not indicate that this was the case.

The present paper calls attention to certain significant features to be observed under the microscope, and offers other evidence pointing to a simple reason for the observed changes in strength. The two phenomena mentioned above (effects of reheating after cold drawing and after quenching) are discussed in detail, and their differing natures set forth.

It will be well to point out first the manner in which the mechanical properties change when cold-worked material is re-

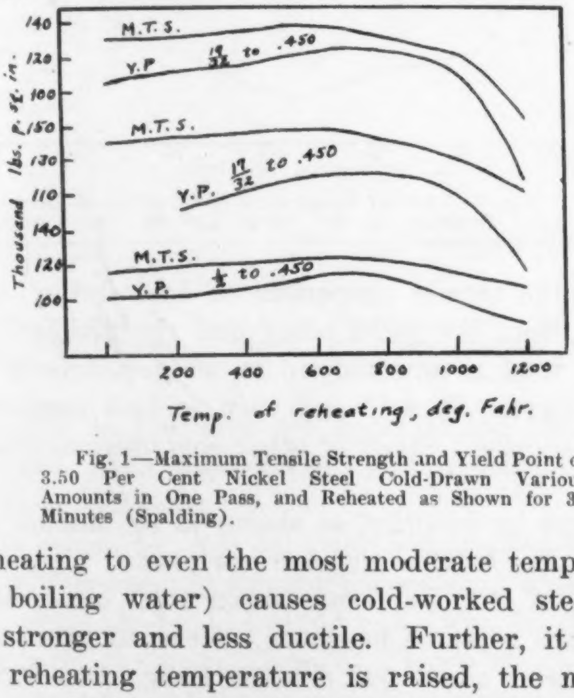


Fig. 1—Maximum Tensile Strength and Yield Point of 3.50 Per Cent Nickel Steel Cold-Drawn Various Amounts in One Pass, and Reheated as Shown for 30 Minutes (Spalding).

heated. Reheating to even the most moderate temperatures (for example in boiling water) causes cold-worked steel to become harder and stronger and less ductile. Further, it is significant that as the reheating temperature is raised, the metal becomes still harder, and this effect becomes progressively more pronounced until a reheating temperature of 600 degrees Fahr. (315 degrees Cent.) has been reached. Above that temperature, the metal begins to lose hardness, at first slowly and then more rapidly, until it finally reaches the condition of full anneal. This progressive change in properties has already been described in the literature, and the experience of the authors is entirely in accord with published data. Three diagrams only are, therefore,

[8]See foot note 2

given, two having already appeared in papers mentioned above. The third is a diagram showing the changes in Rockwell B hardness of the cold-worked specimens which the authors later examined microscopically.

Quite typical of the effect of reheating is the diagram Fig. 1. It is taken from the paper by Spalding[9] and shows the effect of

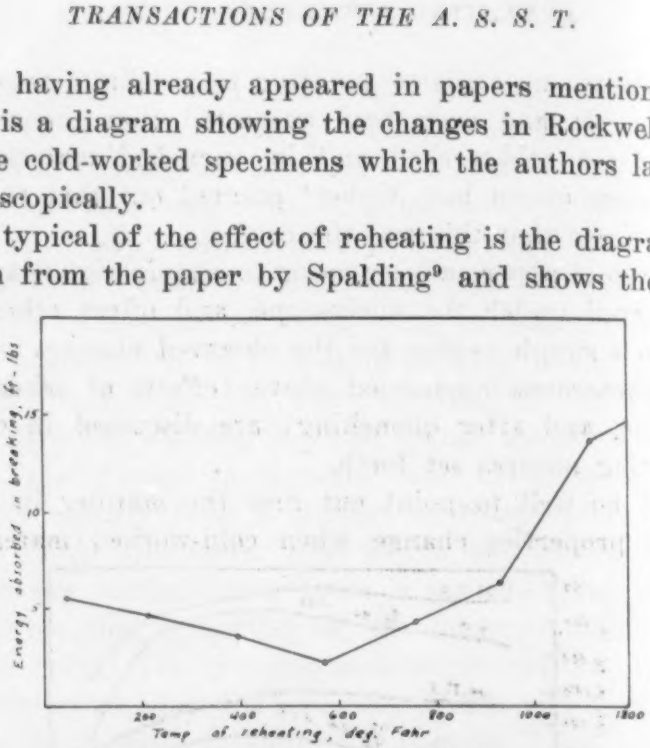


Fig. 2—Effect of Temperature of Reheating on Charpy Impact Toughness of Cold-Drawn 0.30 Per Cent Carbon Steel (Delbart).

reheating on the tensile properties of cold drawn 3.50 per cent nickel steel. Both the yield point and the ultimate strength increase as the steel is reheated up to temperatures of 600 degrees Fahr. (315 degrees Cent.), and then as this temperature is exceeded they decrease. Steels of other compositions behave in quite the same way.

The change in ductility, as shown in the impact test, is illustrated in Fig. 2. In this diagram are plotted a series of Charpy impact values of 0.30 per cent carbon steel which has been cold drawn, and then reheated as shown. Here, too, the extreme point of the curve is at about 600 degrees Fahr. (315 degrees Cent.). As the reheating temperature is raised, beginning at room temperature, the steel shows progressively lower impact values, the toughness reaching a minimum at 600 degrees Fahr. (315 degrees Cent.). Above that temperature the toughness increases once more. Finally, Fig. 3 shows the changes in Rockwell B hardness of the steels examined by the authors. Cylindrical pieces of 3.50 per cent nickel steel were deformed, as illustrated in Fig. 4. The steel had the following composition: carbon 0.16 per cent, man-

[9]See foot note 2.

ganese 0.50 per cent, phosphorus 0.02 per cent, sulphur 0.03 per cent, silicon 0.30 per cent, nickel 3.5 per cent. Cylinders about 1 inch in diameter were flattened as shown, to about half their former diameter. The Rockwell readings were taken in the zones of maximum deformation, as illustrated by the small circles drawn on the face of the specimen in Fig. 4b. The specimens which were flattened had been cut in half with due precautions, one-half being used for microscopic examination and the other half for Rockwell readings. The behavior shown in Fig. 3 is seen to be characteristic of cold-worked steel when it is reheated. Reheating

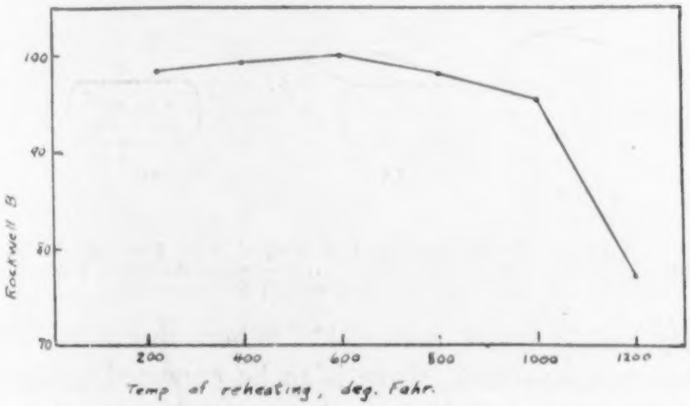


Fig. 3—Rockwell Hardness of Cold-Worked 3.50 Per Cent Nickel Steel, Reheated as Shown. This Steel Examined Microscopically.

causes an increase in hardness, up to reheating temperatures of 600 degrees Fahr. (315 degrees Cent.), and above this temperature the hardness decreases.

A possible reason for this behavior is suggested by the microstructure. Fig. 5 shows the structure developed upon etching the 3.50 per cent nickel steel cold-worked as in Fig. 4. The striations or furrows suggest the usual form of "block slip", their curvature being due to action of the surrounding crystals in preventing free slip along cleavage planes. That is to say, as has been described by others, the grain seems to have been broken up into a number of units which slid past each other while being folded or curved somewhat. It is to be noted that no definite structure is visible within the grains. The material of the furrows is at least too fine (and presumably much too fine) to be resolved at the magnifications employed. That the furrows are visible at all, is held to be due to the fact that cold-worked steel is more soluble

in acids than the steel before cold working. In the present case, the "blocks" which have moved as units within the crystal are not cold-worked. The thin layers between these blocks, however, constitute the material which has been deformed and which has thus acquired a higher solution potential. It, therefore, dissolves more rapidly in the etching acid and so makes possible the detection of the block slip which would otherwise remain invisible.

The theory which the authors wish now to suggest has to do with this minute layer. The layer is presumably very thin in

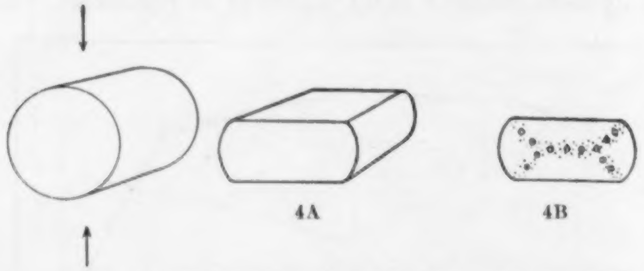
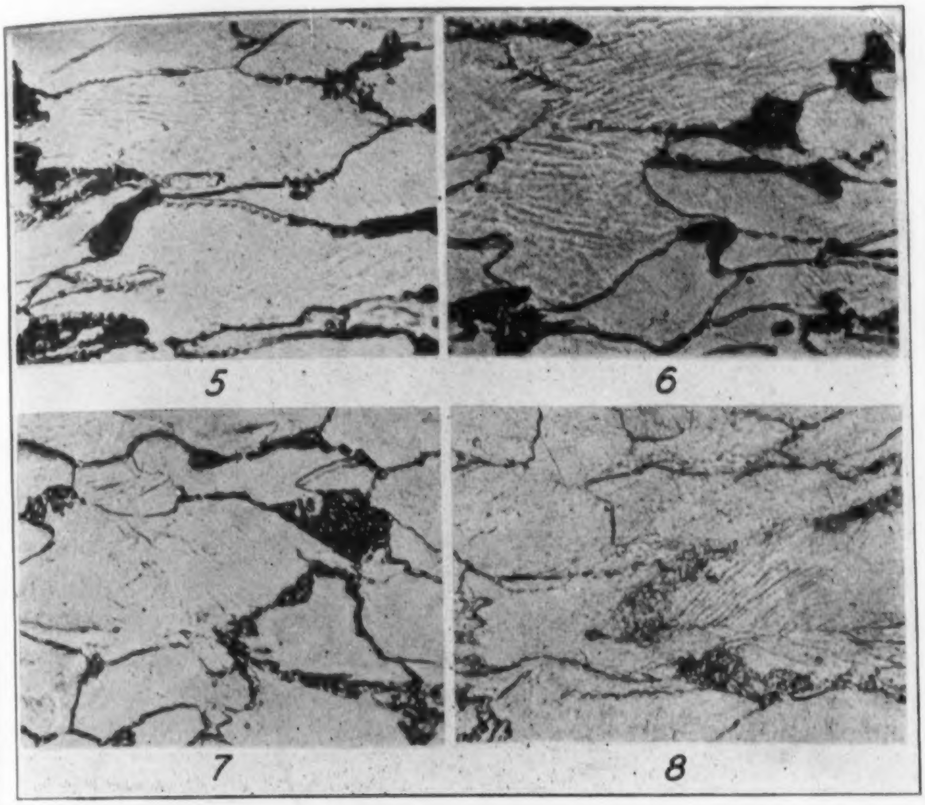


Fig. 4A—Deformation of Cold-Worked 3.50 Per Cent Nickel Steel. In Fig. 4B, Dotted Portion is Region of Maximum Deformation; Circles Show Location of Rockwell Measurements.

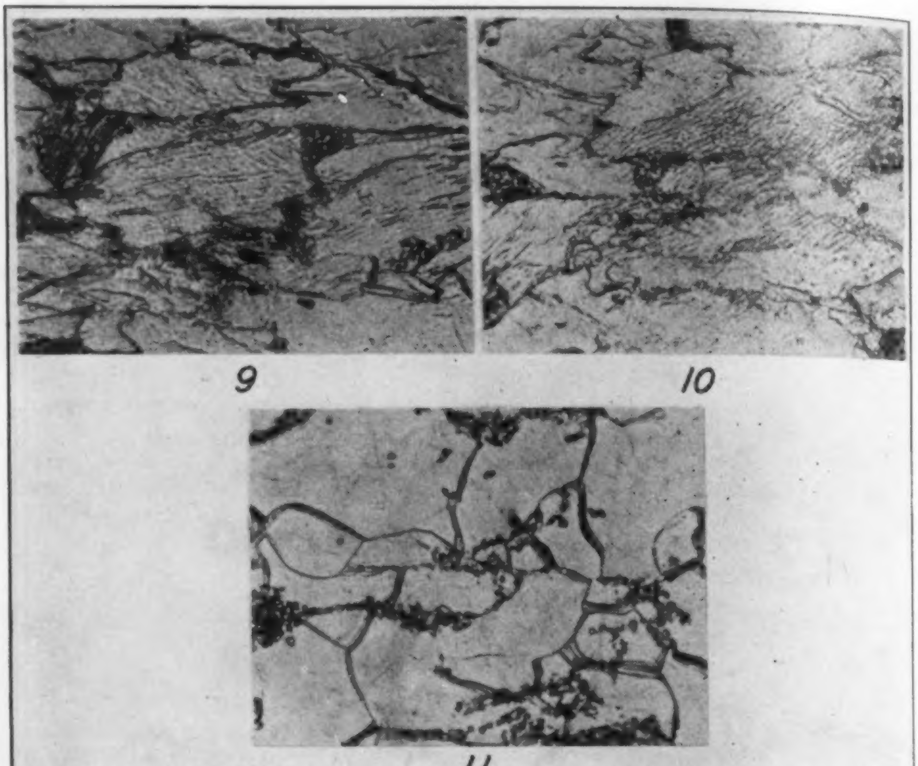
the freshly cold-worked material. When the steel is reheated at very low temperatures, there is to be expected a slight adjustment in crystallinity of this thin layer, in the direction of a definite crystalline orientation of its own, accompanied by a very slight though effective amount of grain growth. The grain growth is only sufficient to cause the effective thickness of the thin layer to increase, without becoming so great as to introduce much potential ductility in the layer itself. The reheating has thus caused the thin layer, because of its now increased size, to be a more effective agent in preventing subsequent deformation of the metal as a whole. The hindering of subsequent deformation in the whole mass naturally involves greater tensile strength in steel which has been reheated in this way, and also lesser impact toughness. Further reheating (still at very low temperatures) increases still more the thickness or grain size and, therefore, the effectiveness of the thin layer. This increase in its effectiveness is promoted by reheating up to temperatures of about 600 degrees Fahr. (315 degrees Cent.). Still further reheating, i. e., beyond 600 degrees Fahr., will of course cause still more grain growth. But apparently by this time the thin layer is so thick that it has itself acquired appreciable ductility. The re-



Figs. 5 to 8—Structures of 3.50 Per Cent Nickel Steel Cold-Worked, Then Reheated as Shown. Magnification 1500x. Fig. 5—No Reheat. Fig. 6—212 Degrees Fahr. Fig. 7—400 Degrees Fahr. Fig. 8—600 Degrees Fahr.

sult is that the piece as a whole begins to soften. Additional reheating beyond this point merely brings about more and more softening.

The series of photomicrographs, Figs. 6 to 11, seems to accord with such a mechanism. Up to 600 degrees Fahr. (315 degrees Cent.), the thin layer remains invisible, even though, with quite the same amount of etching, the furrows seem to become more pronounced. At any rate, at a reheating temperature of 600 degrees Fahr. (315 degrees Cent.), the thin layer is still "submicroscopic" at the resolution available here. With continued rise in reheating temperature, however, the thin layer finally becomes appreciable in thickness. Fig. 10 is characteristic of structures observed numerous times, and shows how the thin layers, which separate the units within the grain, are seemingly of a width now discernible under the microscope. Fig. 11 represents a stage far beyond this, namely, 1200 degrees Fahr. (650 degrees Cent.),



Figs. 9 to 11—Structures of 3.50 Per Cent Nickel Steel Cold-Worked, Then Reheated as Shown. Magnification 1500x. Fig. 9—800 Degrees Fahr. Fig. 10—1000 Degrees Fahr. Fig. 11—1200 Degrees Fahr.

where recrystallization has been complete and the furrows have disappeared.

We thus have a thin layer of "inter-block" material, increasing gradually and continuously in thickness and in definite crystallinity as the reheating temperature is raised. The maximum in strength and minimum in ductility, which is observed at 600 degrees Fahr. (315 degrees Cent.), merely happens to be that stage in the effective thickness of the thin layer, where its interference with deformation is a maximum. If this is the case, certain other properties should change continuously in one direction, without showing any maximum or minimum at 600 degrees Fahr. (315 degrees Cent.). Evidence is plentiful that many properties do actually change in this regular manner. Thus Fig. 12, taken from Heyn,[10] shows the dimensional changes which take place when cold drawn steel wire is reheated at successively

[10]Heyn, Materialienkunde (Springer, 1912); Physical Metallography (Wiley, 1925), p. 228.

higher temperatures. The specific gravity is shown to increase regularly as the reheating temperature is raised from 200 degrees Fahr. (100 degrees Cent.) to 1300 degrees Fahr. (700 degrees Cent.). Further, Fig. 13, also from Heyn,[11] shows how

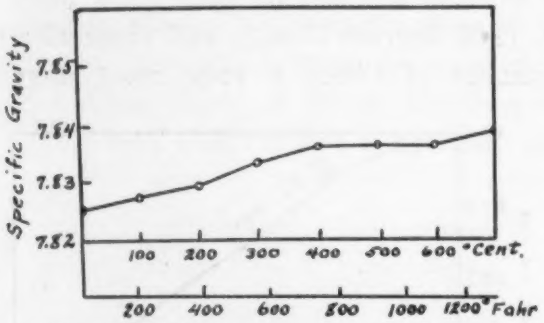


Fig. 12—Effect of Temperature or Reheating on the Specific Gravity of Cold-Drawn Mild Steel Wire (Heyn).

the solubility of cold-worked steel in acid decreases gradually and regularly when similarly reheated. Fig. 14 moreover shows how the electric resistance of a cold-worked steel decreases regularly as the reheating temperature is raised. It is taken from

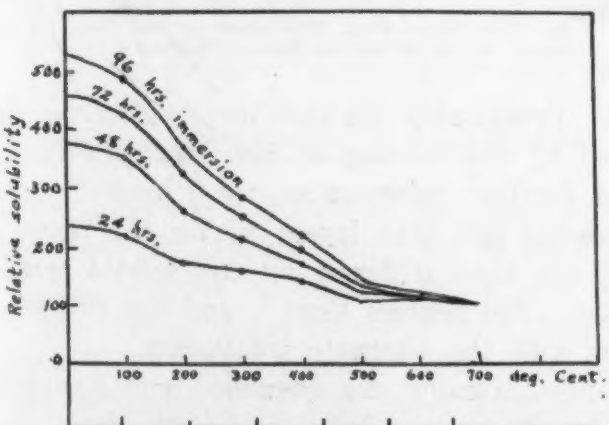


Fig. 13—Effect of Reheating on the Solubility of Cold-Worked Mild Steel in Sulphuric Acid (Heyn).

the paper by Spalding.[12] These changes in the mechanical and physical properties all suggest that the change in the direction of more regular crystallinity is progressive and always in the same direction.

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[11]Heyn, Materialienkunde (Springer, 1912); Physical Metallography (Wiley, 1925), p. 247.

[12]See foot note 2.

Finally, it should be noted that these observations are in accord with the already established great increases in strength to be secured by alternate cold working and reheating. If steel is cold-worked, then heated to say 500 degrees Fahr. (260 degrees Cent.), then cold-worked again, then once more heated to 500 degrees Fahr. (260 degrees Cent.), and these alternate treatments repeated a number of times, a very great increase in strength

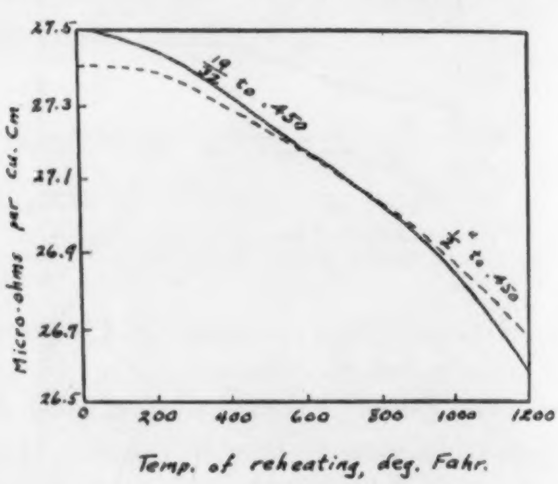


Fig. 14—Electrical Conductivity Curves of 3.50 Per Cent Nickel Steel, Cold-Drawn in One Pass, Reheated for 30 Minutes as Shown (Spalding).

is obtained. Presumably the thin layers after the first treatment are stiffened by the heating to 500 degrees Fahr. (260 degrees Cent.). In further deformation, the "blocks" themselves must deform, forming new thin layers within the blocks. These new thin layers are then stiffened by the second treatment at 500 degrees Fahr. (260 degrees Cent.), and the process continues in this manner with the alternate treatments.

If we now examine the quenched and tempered steels, we find that the phenomena differ materially from the cold drawing effects discussed above. Upon reheating the quenched steels, it is found that the manner in which the mechanical properties progressively change is radically different from the corresponding manner after cold drawing. This will be apparent from the curves of Fig. 15. In observing the changes induced in the cold drawn material when it was reheated, it was noted that even the lowest reheating temperatures introduced an increase in strength and a decrease in ductility, and that this increase in strength and

decrease in ductility became progressively more pronounced with rise in reheating temperature, the effect being a maximum at about 600 degrees Fahr. (315 degrees Cent.). But in the case of the quenched samples, examining for the present only the ductility or Izod toughness curves, we find that there is at first an increase in toughness, (instead of a decrease as in the case of the cold drawn bars) and that this increase becomes more pronounced up to reheating temperatures of about 400 degrees Fahr. (205 degrees Cent.). At this temperature a reversal sets in, and the

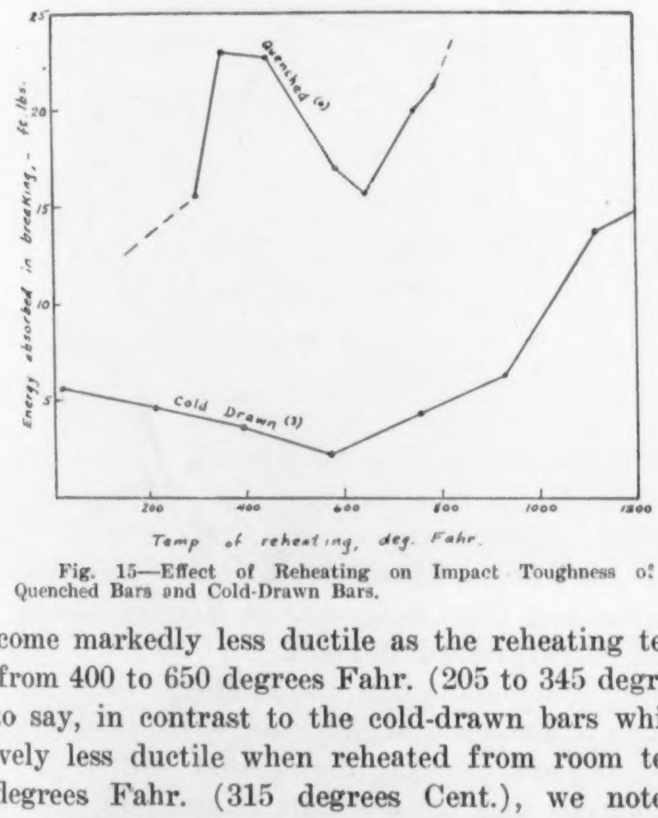


Fig. 15—Effect of Reheating on Impact Toughness of Quenched Bars and Cold-Drawn Bars.

pieces become markedly less ductile as the reheating temperature is raised from 400 to 650 degrees Fahr. (205 to 345 degrees Cent.). That is to say, in contrast to the cold-drawn bars which become progressively less ductile when reheated from room temperature to 600 degrees Fahr. (315 degrees Cent.), we note that the quenched material becomes at first more ductile and then less ductile when reheated in the same range. This is shown in Fig. 15.

The authors wish to review and to amplify at this point the evidence which indicates that in the case of the quenched steels, the decrease in toughness is due to the transformation of retained austenite to non-ductile alpha iron, and then to suggest a simple mechanism accounting for the loss in ductility. Fig. 16 is reproduced from the afore-mentioned paper of one of the authors,[13]

[13]Bain and Grossmann, The Nature of Oil-Hardening, Non-Deforming Tool Steels, TRANSACTIONS, American Society for Steel Treating, Vol. 10, December, 1926, p. 883.

and shows the dimensional changes in a quenched low-alloy steel when it is reheated to progressively higher temperatures. The curve may be considered to consist of three portions, viz., (1) the contraction up to about 350 or 400 degrees Fahr. (180 or 205 degrees Cent.), (2) the relative expansion from 400 to about 550 degrees Fahr., and (3) the final contraction beyond 550 degrees Fahr. (285 degrees Cent.). The initial contraction (1) is held to be due to the tempering of the martensite, while the retained

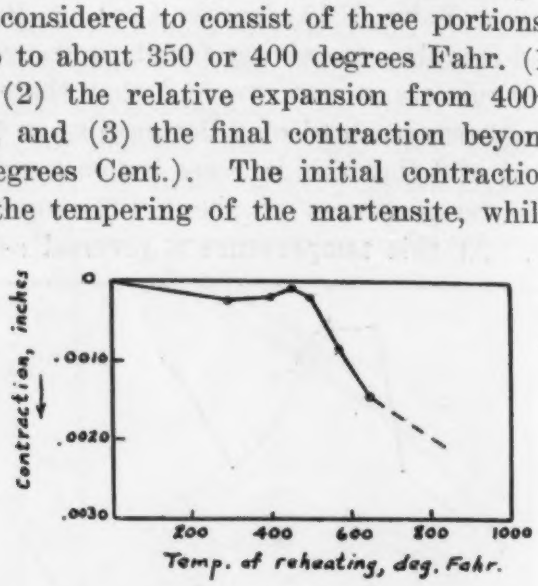


Fig. 16—Dimensional Changes in Reheating 2.50 Inches Long Cylinder of Quenched (Hardened) Chromium-Molybdenum Steel.

austenite is stable and takes no part in the reaction. In the stage (2) the retained austenite transforms to fine-grained alpha iron and, therefore, expands, the effect being observed even though the original martensitic alpha iron is still contracting. In stage (3) the alpha iron from both sources is progressively tempered and becomes coarse-grained and soft.

Evidence is abundant that the austenite which was retained in the quench is destroyed at this point 400 to 600 degrees Fahr. (205 to 315 degrees Cent.). Heindlhofer and Wright[14] showed by X-ray analysis that the austenite retained in a steel with 1.0 per cent carbon and 1.2 per cent chromium was destroyed in this range. E. C. Bain's X-ray evidence in a paper with one of the authors[15] showed a similar disappearance of austenite in a steel containing 0.85 per cent carbon and 1.5 per cent manganese. Furthermore, it has been shown repeatedly[16] that the transforma-

[14]Heindlhofer and Wright, Density and X-ray Spectrum of Hardened Ball Steel, TRANSACTIONS, American Society for Steel Treating, Vol. VII (1925), p. 34.

[15]Grossmann and Bain, On the Nature of Some Low-Tungsten Tool Steels, TRANSACTIONS, American Society for Steel Treating, Vol. 9 (Feb., 1926), p. 259.

[16]See foot notes 6, 13, 15.

tion of the austenite is accompanied by a decrease in ductility (a "brittle range"). The purpose in reviewing this evidence here is to introduce a suggestion of a probable and simple mechanism accounting for the loss of ductility.

In suggesting the proposed explanation, it is desirable to cite a similar case which is found in certain high chromium irons. If a chromium iron containing 18.0 per cent chromium and 0.10 per cent carbon is heated from the annealed state to 1850 degrees Fahr. (1010 degrees Cent.) and quenched, it will be found

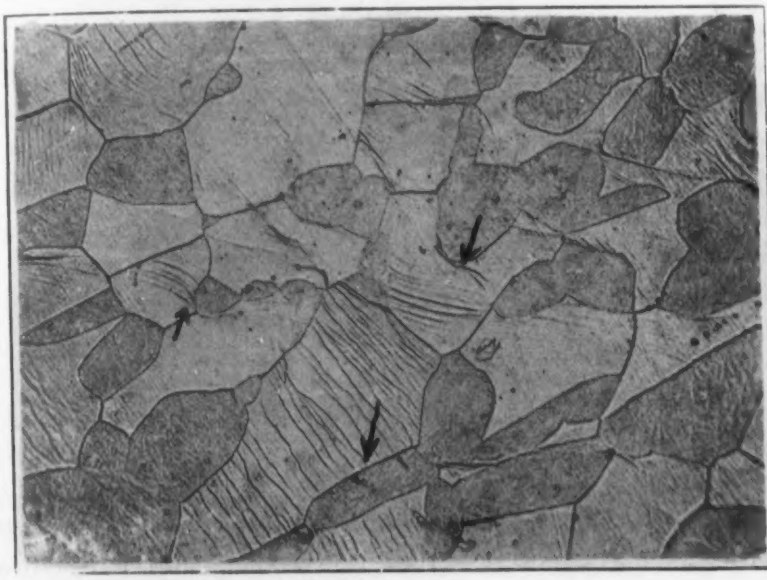


Fig. 17—Slip Lines in a High-Chromium Iron. Arrows Point to Obstructed Slip, Due to Presence of Martensite Grains. Magnification 250x.

to have increased slightly in strength and decreased considerably in ductility. In a consideration of this phenomenon[17] it was pointed out that the loss in ductility was undoubtedly due to the formation of numerous regions of martensite (non-ductile), which were distributed through a mass of ductile ferrite. Fig. 17, reproduced from that paper, shows a piece of the chromium iron in this less ductile condition. The piece has been polished and etched, and then deformed in a vise to develop the slip lines. It will be noted that the slip lines are found only in the ductile ferrite, with none in the martensite, and that the slip lines in the ferrite are forced to curve around the martensite grains because

[17] M. A. Grossmann, Behavior of Carbon in a High-Chromium Rustless Iron, TRANSACTIONS, American Society for Steel Treating, September, 1926, p. 436.

of the hardness of the latter. This reduced ductility is observed both in tensile tests and in impact toughness tests.

It is a similar mechanism which probably accounts for the loss of ductility produced in quenched steels by reheating. A certain amount of austenite has been retained in the quench, and is associated with "martensite", alpha iron. When the quenched steel is reheated, the lowest reheating temperatures cause the "martensite" to soften somewhat, while the retained austenite remains stable (and, therefore, ductile). In this first reheating stage, therefore, the steel becomes progressively more ductile, due to the softening of the martensite. Presently a reheating temperature is reached, however, where the austenite is decomposed to fine-grained, non-ductile, alpha iron. The former ductile austenite is now replaced with non-ductile regions of fine-grained alpha iron. These non-ductile regions interfere with deformation of the now softened matrix in the same manner as do the martensite regions in the high-chromium iron discussed above. This conception is illustrated in Fig. 18. It constitutes the second stage, or brittle range, in the reheating of quenched steels. With further heating to higher temperatures, the third stage or final softening is reached, where the alpha iron from both the original martensite and the now transformed austenite is rendered soft and ductile.

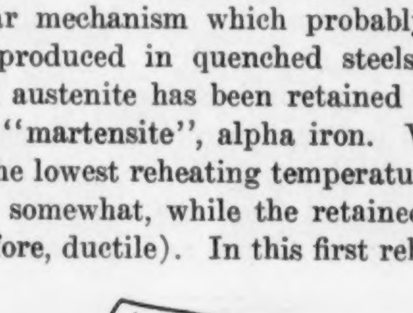


Fig. 18—Probable Nature of Deformation of a Quenched and Tempered Steel, in the Brittle Range. Dotted Portion: Tempered (Soft) Martensite. White Spines: a Few of the Layers of Austenite Just Transformed to Hard Alpha Iron. Wavy Lines: Slip Bands. Arrow Points to Obstructed Slip.

To summarize, then, it should be noted that in the case of the quenched and tempered steel, the brittleness at 400 to 600 degrees Fahr. (205 to 315 degrees Cent.) is the result of the appearance of a new structure. It has been shown by volume meas-

urements, by X-ray analysis and by observation under the microscope, that in this range of temperature retained austenite is converted to alpha iron.

This reason for loss of ductility is in contradistinction to that in the cold-worked steel, where any reheating causes only a continuous progressive change in crystallinity. The maximum strength (and brittleness) at 600 degrees Fahr. (315 degrees Cent.) is held to be due to the growth of a thin crystalline layer to critical size at this temperature.

General Summary

Data on the reheating of cold-worked steel as well as of quenched steel are examined. Cold-worked steel becomes progressively less ductile when it has been reheated at low temperatures up to 600 degrees Fahr. (315 degrees Cent.), and then after passing that temperature becomes progressively more ductle. There is evidence to support the hypothesis that these phenomena originate in the amorphous metal produced by cold work. The grains of the metal appear to deform by "block slip", the regions between the blocks becoming amorphous. Low-temperature reheating causes hardening due to the amorphous layers, presumably by the growth of the thin layers which obstruct deformation. The lowest temperatures merely cause the thin layers to grow to effective size, but reheating to higher temperatures causes them to grow to such size that they become ductile and are no longer effective in obstructing slip.

In the reheating of quenched steels, the brittle range which develops in the neighborhood of 600 degrees Fahr. (315 degrees Cent.) is due to the presence of non-ductile transformed austenite in a matrix of tempered martensite. The non-ductile regions obstruct the deformation of the softer matrix.

DISCUSSION

Written Discussion: By H. M. German, metallurgist, Universal Steel Company, Bridgeville, Pa.

Messrs. Grossmann and Snyder are to be congratulated for their explanation of the cause of hardening by reheating after cold working. This theory, I believe, also explains the effect of a process known as "stiffening," which has been practiced by saw and cutlery manufacturers for many years.

For example, a cast steel temper hand saw after tempering has a

scleroscope hardness of approximately 70 and will spring in such a manner that the point can be made to touch the butt and upon release of the pressure the saw will again assume a straight line. After the succeeding operations of flat grinding, taper and draw grinding, and glazing have been performed the scleroscope hardness will be raised to 78 to 80, but in this condition the saw will have lost its spring. By a process of "stiffening," which consists of heating the polished saw in oil at a temperature of 420 degrees Fahr. for three to five minutes, the spring of the saw will be returned and it will stand the same test as explained after tempering. Saws which lose their stiffness or spring in operation can also be restored by the "stiffening" operation. Temperatures exceeding 420 degrees Fahr. are seldom used on bright polished work for above this temperature the heated articles take on the characteristic oxide tempering colors. Dry heat is fully as effective as heated oil for "stiffening."

Written Discussion: By R. S. Dean, Western Electric Company, Chicago.

The question of hardening produced in cold-worked steel and iron by reheating seems in need of a critical examination. At the 1926 meeting of

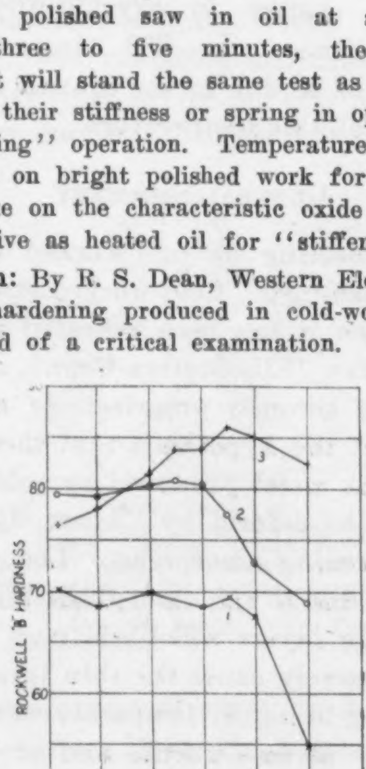


Fig. 1—Irons Cold Rolled to 33⅓ per cent Reduction in Thickness and Annealed at Temperature Indicated for 1 Hour Periods. Curve 1 Vacuum Melted Electrolytic Iron; Curve 2 Ingot Iron; Curve 3 Air Melted Electrolytic Iron.

the Institute of Metals Division, Professor Clayton,[1] presented data showing such an increase in hardness on cold-worked ingot iron. Mr. Archer stated this year, in a discussion of a paper by Mr. Gregg and myself,[2] that work done at Case showed that this increase in hardness was accompanied by an increase in electrical conductivity. Mr. Archer seemed to think this was

[1]The Effect of Annealing Upon the Hardness of Cold-Worked Ingot Iron—by Chas. Y. Clayton—*Transactions,* American Institute of Mining and Metallurgical Engineers, Vol. 73, 1927, page 926.

[2]General Theory of Metallic Hardening—by R. S. Dean and J. L. Gregg—*Proceedings,* Institute of Metals Division, 1927, page 368.

evidence in favor of the slip interference theory. I think we will all agree that the simplest explanation of all these hardening by reheating phenomena is that some constituent is by this process produced in the proper degree of dispersion for hardening. The function of the cold work is to expedite the agglomeration of this constituent to critical size. That cold work exerts such an influence on the agglomeration of disperse constituents has been shown by our work on lead-antimony.[3]

Before inventing new theories it would seem to me that this more or less obvious explanation be tried. A critical test, of course, is to repeat the experiments on very pure iron. Mr. Gregg has been good enough to do this. His curves are shown in Fig. I and are practically self-explanatory. With the purest iron obtainable there is no hardening by reheating after cold work, but with the same iron melted in air the hardening is very marked. It appears then that the hardening is due to the separation of disperse constituent, probably an oxide or nitride.

Written Discussion: By F. C. Langenberg of Climax Molybdenum Company of New York City.

The authors of this paper, Marcus Grossmann and C. C. Snyder, are to be congratulated for the hypothesis presented to explain the phenomena of increased strength following low temperature reheating after cold-work.

It is of interest to note that the temperature of 315 degrees Cent., proposed by the authors as producing the greatest increase in strength, is approximately the same temperature found to produce the highest strength in cylinders that have been expanded by the auto-frettage, or internal hydraulic pressure method. From data obtained by testing cylinders at various percentages of expansion followed by low temperature reheating the following table of average per cent increases in strength was prepared.

Reheating Temperature	Per cent Increase in Strength for Enlargement Noted.		
Degrees Cent.	3%	6%	9%
121	2.3	2.1	0.45
250	11.5	6.5	6.45
300	—	11.77	10.6
325	13.58	8.34	2.44
400	0.	0.	0.

On the basis of these results a reheating temperature of 300 degrees Cent. has been standardized for all guns manufactured by the coldworking process. It is believed for production purposes a temperature of 300 degrees Cent. is preferable to one slightly higher as the strength increase shows a more rapid drop as the temperature is increased from 300 degrees Cent. than when it is decreased, and therefor a reasonable variation in temperature control will not be so apt to affect appreciably the final results.

Tests indicate that the hysteresis effect obtained when cylinders are

[3]The Lead-Antimony System and Hardening of Lead Alloys (discussion)—by R. S. Dean, L. Zickrick, and F. C. Nix—*Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 73, 1927, page 539.

expanded beyond the yield point of the material is practically moved by a reheating at 300 degrees Cent. following cold working. The width of the hysteresis loop decreasing as the reheating temperature is raised to 300 degrees Cent. and then recurring at 325 and 400 degrees Cent.

Oral Discussion

DR. ZAY JEFFRIES: It is a very interesting point brought out by Mr. Dean, that no age hardening is developed in the pure electrolytic, vacuum melted iron. The Rockwell B hardness of that material is 70.

In some experiments to be described tomorrow in a paper by Mr. Sykes and myself, we have made similar tests on a variety of iron, which we call pure iron, obtained by hydrogen reduction from the pure materials, and by soaking for a long time in hydrogen so as to remove the carbon to such an extent that chemical analysis fails to find any. Also, there is supposed to be no other material present. That there is very little material in solid solution, either oxygen or nitrogen or anything else, is indicated by the fact that the Rockwell B hardness is only 43, whereas the Rockwell B hardness of Mr. Dean's pure iron was 70.

We get very definite age hardening at 100 degrees Cent. after strain hardening in this variety of iron, so we came to the conclusion that pure iron is susceptible to the age hardening after cold working.

This theory of Grossmann and Snyder is essentially the theory of Archer. The observations are very old, going back into the last century, but I believe Fetweiss and Archer independently, if not simultaneously, came to the conclusion that the recovery of elasticity after over-strain, at room temperature, was definitely associated with what has been called the blue heat phenomenon in iron and steel.

I think there is no question in anyone's mind about the relation between the blue heat phenomenon at from 300 to 600 degrees Fahr. and the slow changes of properties at room temperature after cold working, but the theory which Mr. Archer advanced to account for this, which Mr. Fetweiss did not, was this; when iron is cold-worked at room temperature, for some reason or other, not explained, many of the slip planes are not strengthened, as was called for by the Bielby theory, but they are actually weaker than the remaining crystalline material. That, by the way, is another thing which is not explained by Mr. Dean's suggestion. There is no reason why these slip planes should be weak just because other material is in solid solution. When the deformation is effected at a temperature of 400 or 500 degrees Fahr., the slip planes strengthen during the deformation and the material appears to be fairly hard, but it takes two weeks or thereabouts to effect complete strengthening of the slip planes at room temperature.

Dr. Rosenhain has confirmed this in a very pretty way in connection with the formation of Neumann bands in iron. He finds that if annealed iron is deformed very rapidly, Neumann bands form freely. If, however, the annealed iron is first deformed by slow loading and then is deformed by rapid loading, no Neumann bands form, but the subsequent deformation takes place along the old slip planes.

To explain the hardening on aging after cold working and on re-heating, Archer's view was that the weakened slip planes "healed," not by becoming fine-grained crystals, which idea I believe is the distinct idea of Grossmann and Snyder, but by a better bonding of the adjacent fragments along slip planes. A bonding or healing so that the "slip plane strength" is equal to the "crystal strength" is all that is required.

When examined critically, I think, the idea of Archer is very much preferable to that of Grossmann and Snyder, because this phenomenon is apparent with very mild deformation, and with such mild deformation, we have no evidence of the formation of these minute crystals growing out to form the wider crystals at the higher temperatures. In fact, a temperature, after this mild deformation, of something like 650 degrees Cent. is required in order to find any new crystals, whereas this hardening will take place slowly at room temperature.

C. C. SNYDER: I wish to thank these gentlemen for their discussion of this phenomena. Speaking of the irons as pure irons, it may be that, due to the absence of carbon and the alloys in the ingot irons, the conclusions they have reached might probably be different. I hope that this subject will call for more discussion at a future time.

DR. C. H. HERTY: I would like to say just one word about the hardening of the steel that was melted under air. We have been making some melts at the Bureau of Mines of quite high oxygen content and in testing these for hardness, we note that as the oxygen content of the steel increases, there is a very regular increase in hardness above the saturation point for oxygen. That is, 0.2 per cent oxygen is the saturation point for oxygen in steel and at that concentration there is an increase in hardness over pure iron; and as the oxygen increases above 0.2 per cent there is a regular increase in hardness.

J. L. GREGG: I would just like to make a remark about the purity of the iron referred to by Mr. Dean. The iron he spoke of, with a Rockwell hardness of 70, had been cold-rolled, and, as I understand it, the iron to which Dr. Jeffries referred, having a Rockwell hardness of 43, was annealed iron, which would probably explain the difference.

DR. J. A. MATHEWS: I do not quite understand what Dr. Jeffries stated in regard to the slip lines. The production of the slip lines by the cold drawing itself initially hardens and strengthens the material. The presence of those slip lines is certainly not a cause of softness. Even after you heal them, then you have not produced the condition that you had before the steel was cold drawn.

I was very much interested in Mr. Grossmann's paper, possibly because I more or less suggested the idea to him. In fact, his earlier paper on the effect of re-heating heat treated steels, as he says in his paper, was suggested by some remarks of mine. A little later we were discussing that feature of re-heating heat treated steels and I asked him how he explained the fact that cold drawn steels behaved the same way at about the same temperature, so he apparently started some work on that suggestion and has presented today what seems to be a very good case and explanation.

There is one suggestion I would like to make, in Mr. Grossmann's absence, to Mr. Snyder. This temperature of 600 degrees Fahr. is not a fixed temperature, it is the usual one for a great many of the ordinary alloys. I think in the case of stainless steel or iron we have found that the shock resistance was at a minimum at a tempering of about 800 degrees Fahr. after quenching. I would like to see them try this same experiment on stainless iron, about 12 per cent chromium—that is, the kind that will harden—and see if the two temperatures happen to coincide again at about 800 instead of 600 degrees Fahr. It is a strange coincidence that in the cases so far discussed, the two temperatures do coincide at about 600 degrees Fahr.

Authors' Reply to Discussion

The authors would like to express their appreciation of the numerous discussions presented, and wish to reply to each individually.

The observations with regard to saws presented by H. M. German are most interesting as a practical example of the effect of low temperature reheating.

With regard to Mr. Dean's discussion, it seems difficult to accept the view that the function of the cold work is to expedite agglomeration of some constituent, such as oxide or nitride. As regards the evidence of his Fig. 1, the curves show considerable irregularity. The irregularities in curve 1, in the range up to 300 degrees Cent. are 1½ points Rockwell B, which is more than the total increase in curve 2 for ingot iron, in that range of temperature. Also, curve 3 shows a total increase of about 10 points Rockwell B, a most unusual rise. Further, no analysis is given for the pure iron. Our experience shows that vacuum-melted electrolytic iron is not by any means necessarily free of oxygen, as shown by analysis by vacuum fusion (Bureau of Standards method).

The authors appreciate the introduction of the additional evidence and comments by Dr. Langenberg, giving interesting data on the effect of repeated treatments. It is believed that the conception of critical size of the thin layers of "inter-block" material is pertinent here.

The authors appreciate also Dr. Jeffries' comprehensive discussion, but still feel compelled to hold views diverging from the "healing" theory. Presumably, in compliance with accepted usage, the term "healing" is used to indicate a return from a state of injury or disturbance, to a state of identity with (and continuity with) surrounding material of the same kind, or with original material from which the disturbed part was first formed. In other words, healing presumably in this case means a tendency to return to the crystalline state, the adjacent crystal fragments growing into the gradually healing layer. This conception seems to us to be deficient in two important particulars. First, if the resultant better atomic bonding, due to healing, is the cause of the increase in strength, then still further healing, i. e. beyond 600 degrees Fahr., (300 degrees Cent.) should cause still stronger atomic bonding, with a further increase in strength, which is not the case. Second, if the slip planes heal, they should become

(Continued on Page 281)

EVALUATING QUALITY IN HEAT TREATED HIGH SPEED STEEL BY MEANS OF THE MILLING CUTTER

By J. B. Mudge and F. E. Cooney

Abstract

A test of heat treated high speed steel in the form of milling cutters, the variables having been reduced to a minmum, and the dulling point of the cutting edges of the tools determined by a recording wattmeter connected in the circuit of the motor of the milling machine. A "deadline" test resulted instead of the usual "breakdown" test.

It was found that:

Cutters of the same steel hardened by the same method check within limits that are sufficiently close for test purposes.

No cast cutter has been found to give results comparable to standard high speed steel refined by suitable working. Cutters hardened by patented or salt bath processes have not given results comparable to standard high speed steel hardened by the open fire method.

Introduction

THE problem of evaluating quality in heat treated high speed steel cutting tools is one to which the authors have given considerable thought in an effort to determine the degree of excellence between various heat treated steels.

The lathe tool breakdown test has received considerable attention by Taylor, French, and others, and it was only after a careful resumé of their work and the requirements of the Western Electric Company that it was decided to use the milling cutter test, because the milling cutter is our most important cutting tool. Our production milling requires the removal of fairly light cuts with sharp tools so as to produce a smooth finish with a minimum of burr in the manufacture of telephone apparatus piece parts. Furthermore, our lathes being all of the direct motor-driven type, do not lend

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. Of the authors, who are members of the society, J. B. Mudge is metallurgical engineer with the Western Electric Co., Chicago, and F. E. Cooney is associated with Mr. Mudge at the same Company. Manuscript received August 19, 1927.

themselves readily to adjustment for a constant surface cutting speed throughout the test.

It is realized that in a test of this type or any other test for evaluating tool steel quality all variables other than the steel and its heat treatment should be minimized to the point where results can be duplicated, otherwise the testing method is open to adverse criticism.

Equipment and Methods

In selecting a milling cutter for this test, the following points were considered:

1. Each tooth must be capable of removing a fairly large, deep chip.
2. The face of the tooth form must be undercut, i. e., have sufficient rake so as to give a free cutting action, more nearly like the action of a lathe tool and differing from the pushing or dragging action of the radial-faced tooth milling cutter.
3. Ample clearance must be provided for the chips to clear themselves.
4. Chatter resulting from a cutter having too many teeth causing the chips removed per tooth to be so small that the cutter tends to slip over the surface of the work and spring the arbor, must be minimized.
5. It was felt that the life of the test cutters would be unduly prolonged if spiral-shaped teeth were included.

Based on the above, the coarse-tooth type side milling cutter (refer to Fig. 1) was selected. This form of cutter has the added advantages of being relatively inexpensive and lends itself readily to commercial manufacture.

In preparing the cutters for test, extreme care was exercised in grinding and lapping the arbor hole as well as grinding the tooth clearance. Before heat treatment the arbor holes were left from 0.015 to 0.020-inch undersize so that sufficient metal will be left to preserve continuity of the ground surface should the hole open excessively in heat treating. This hole was then ground to within 0.002-inch of the finished dimension, the remaining metal lapped to a snug sliding fit on a special arbor ground to the exact dimensions of the arbor used on the test milling machine. This

special arbor which was only about 8 inches in length was mounted between the centers of the grinding machines and the cutter to be sharpened slid back and forth on its surface across the face of the grinding wheel. Before removing the arbor and cutter from the

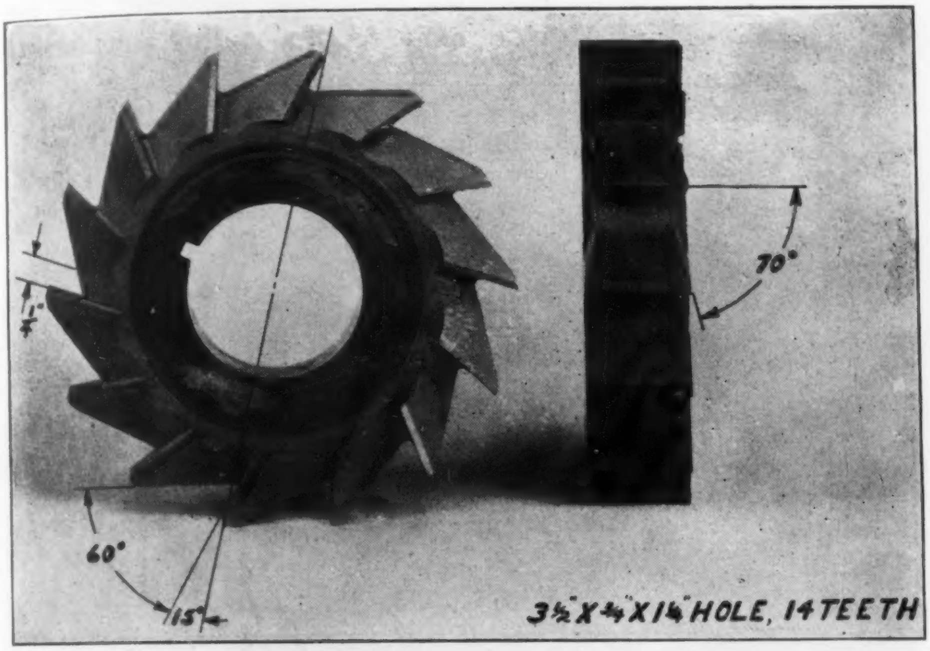


Fig. 1—Characteristics of the Cutter Used as a Standard of Design and Comparison in the Tests Described in This Paper. Cutters are made from Bar Stock with Standard Keyway. Cutter Dimensions are 3½x¾ with a 1¼ inch Hole.

grinding machine centers, a check was made on the tooth clearance as well as the concentricity of the cutter teeth, by means of a clearance gage and indicator gage graduated to 0.001 of an inch. No variation in the height of the cutter teeth was permitted; they must check dead true.

When the cutter was mounted on the arbor of the milling machine an allowance of 0.001-inch in concentricity was permitted as we found it practically impossible to make or buy an arbor twenty-four inches long that would run perfectly true. These precautions reduced to a minimum the variable of all teeth not doing the same amount of work.

The milling machine used (Fig. 2) was a Brown and Sharpe 2-B Heavy Type with automatic longitudinal, transverse, and vertical feed. It was run at a spindle speed of 136 revolutions per minute which, with a 3½-inch cutter ground as shown in Table I,

gave a cutting surface speed of 122.7 to 124.2 feet per minute. This difference proved negligible, besides each cutter was treated the same. The table feed was 5 inches per minute and the depth of cuts 0.125-inch.

A portable graphic recording polyphase wattmeter was connected in the circuit with the motor of the milling machine and

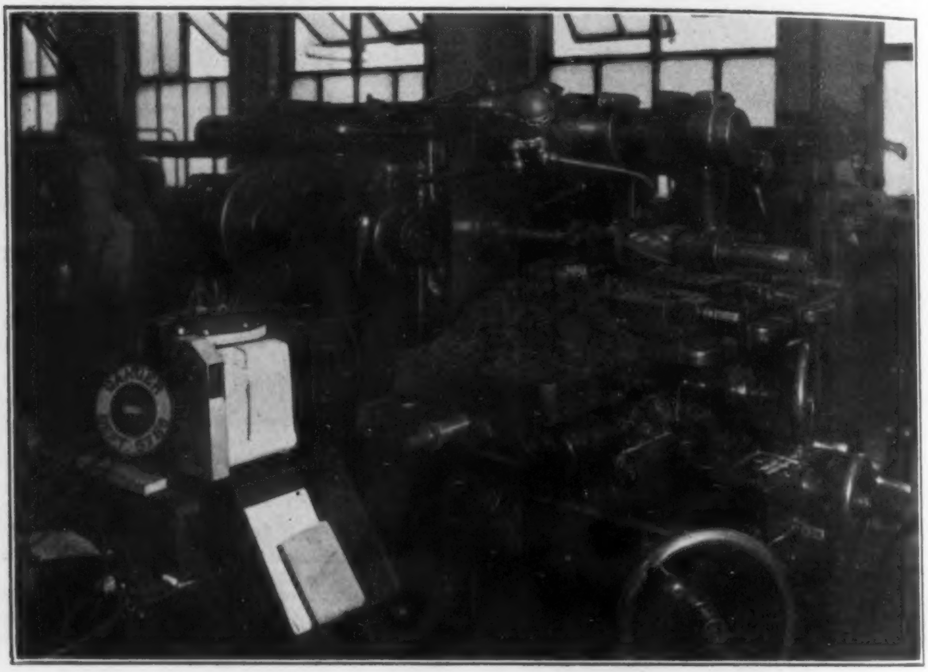


Fig. 2—Milling Cutter Test Set-up.

after several trial runs "deadlines" were established which governed all future tests. This point was chosen by determining the power increase required for cutting, by a tool which judged dull, could still be resharpened by the removal of approximately 0.010 to 0.015-inch. As the cutter dulled, the increased load on the motor was automatically recorded, and any question of personal opinion as to the relative condition of the cutter was removed.

The test logs were forged chromium-nickel steel (S. A. E. 3345) bars, three and one-half inches square and thirty inches long, oil quenched and tempered to 285-302 Brinell. Four longitudinal cuts 0.125-inch deep were taken across the bar, after which the five remaining projections were removed. (Fig. 3.) This was done by shifting the table transversely under a surface spiral mill mounted on the same arbor as the test cutter (Fig. 2). The test bar was then

moved under the test cutter and four more cuts taken, etc., until the cutter was dull. In this manner each cutter was at all times removing the same amount of metal and also had the same amount of side cutting friction.

The coolant used was a soluble oil and water mixed in the ratio of one to sixteen. Its flow was regulated by a needle valve which

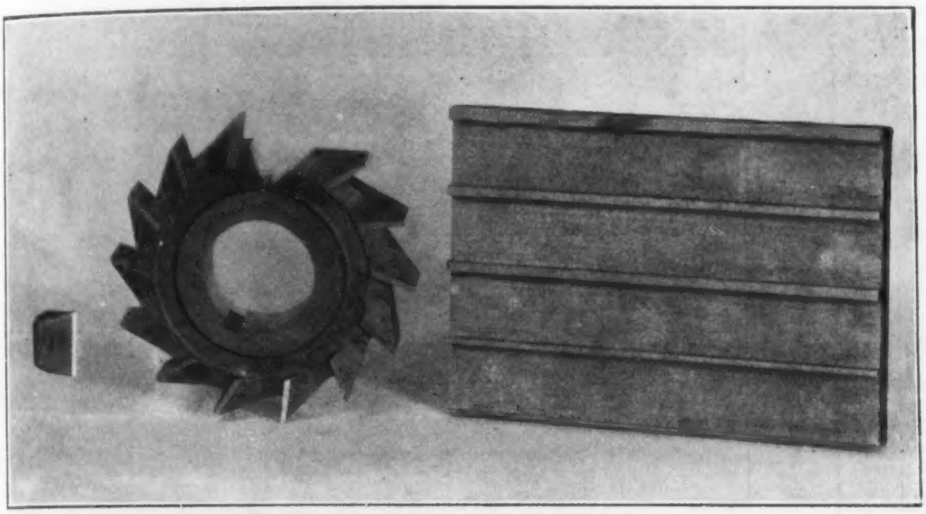


Fig. 3—Photograph Showing one of the Test Cutters with Tooth Removed for Examination. Longitudinal section showing surface of test log is also shown.

permitted one drop per second to fall on the rotating cutter. This was determined after several trials as being satisfactory for the purpose and did not unnecessarily prolong the life of the cutting tool.

The cutters used for establishing the ability of this test to duplicate results were made from selected material and heat treated in a gas-fired double-deck furnace, automatically controlled by means of proportional mixers and recording controllers to permit a temperature control of 2350 degrees Fahr., ± 15. All cutters were preheated at 1700-1750 degrees Fahr., then brought up to 2350 degrees Fahr. ± 15 quenched in oil and tempered for two hours at 1050 degrees Fahr. ± 10. By referring to Table I it will be seen that cutters 12, 17, 22, and 24, taken from the same bar, hardened by the same concern using identically the same method, ran within 0.56 lineal feet of each other.

Discussion

The results herein described cover the testing of approximately

Table I

Cutter No.	Heat Treatment	Type Steel	Rockwell C Scale	1st Grind (.010")***	Test Log	2nd Grind (.015")***	Test Log	3rd Grind (.030")***	Test Log	Average of 3 Grinds	Per Cent Rating
20	O. F.	18-4-1	61	24.5′	D1H (293)*	28.6′	D3H (285)*	30.0′	D5H (302)*	27.7′	100.
27	O. F.	18-4-1	60	21.0′	D3H (285)	30.0′	D5H (302)	31.0′	D7H (302)	27.3′	98.5
13	O. F.	18-4-1	64	22.1′	D1H (293)	27.5′	D4H (293)	27.5′	D6H (302)	25.7′	92.7
11	O. F.	18-4-1	64	19.6′	D1H (293)	25.0′	D4H (293)	30.0′	D6H (302)	24.86′	89.7
****12	O. F.	18-4-1	65	18.2′	D1H (293)	23.6′	D4H (293)	28.9′	D5H (302)	23.56′	85.0
**26	O. F.	18-4-1	64	27.5′	D8H (293)	17.0′	D9H (302)	25.0′	D10H (285)	23.16′	83.6
****17	O. F.	18-4-1	64	19.6′	D1H (293)	23.6′	D3H (285)	26.0′	D5H (302)	23.06′	83.2
****22	O. F.	18-4-1	64	20.0′	D8H (293)	22.0′	D9H (302)	27.0′	D9H (302)	23.00′	83.0
****24	O. F.	18-4-1	63	20.0′	D8H (293)	22.0′	D9H (302)	27.0′	D9H (302)	23.00′	83.0
28	O. F.	14-4-2	64	16.0′	D1H (293)	26.5′	D4H (293)	22.5′	D6H (302)	21.66′	79.1
23	O. F.	18-4-1	65	20.0′	D8H (293)	22.5′	D9H (302)	23.0′	D9H (302)	21.83′	78.8
15	O. F.	18-4-1	63	17.2′	D1H (293)	24.0′	D3H (285)	23.7′	D7H (302)	21.63′	78.0
25	O. F.	18-4-1	64	20.0′	D8H (293)	21.0′	D9H (302)	23.0′	D10H (285)	21.33′	77.0
31	O. F.	18-4-1-Co.	65	19.6′	D1H (293)	22.6′	D4H (293)	20.0′	D6H (302)	20.73′	74.8
14	S. B.	18-4-1	65	17.5′	D3H (285)	17.0′	D4H (293)	17.5′	D7H (302)	17.33′	62.5
16	P. P.	18-4-1	63	13.0′	D1H (293)	19.1′	D3H (285)	19.4′	D5H (302)	17.16′	61.9
18	P. P.	18-4-1	59	9.8′	D1H (293)	18.0′	D3H (285)	22.5′	D5H (302)	16.76′	60.5
10	S. B.	18-4-1	64	11.0′	D1H (293)	16.0′	D3H (285)	19.5′	D6H (302)	15.5′	55.9
19	P. P.	18-4-1	58	5.0′	D1H (293)	13.0′	D1H (293)	22.6′	D5H (302)	13.53′	48.8
30	C.	Cast	65	5.0′	D4H (293)	5.0′	D5H (302)	5.0′	D6H (302)	5.0′	18.0
21	C.	Cast	63	4.1′	D3H (285)	5.0′	D5H (302)	5.0′	D6H (302)	4.7′	16.9

BREAKDOWN TEST

Cutter No.	Heat Treatment	Type Steel	Rockwell C Scale	4th Grind	Test Log	Per Cent Rating
27		18-4-1	60	55′	D8H (293)	100.
28		18-4-1	64	32.5′	D8H (293)	59.

*Brinell Number of test log.
**No. 26 on the 4th Grind on bar D10H (285) cut 20′.
***Amount of metal removed on each grind.
****These four cutters are the same steel, heat treated by the same concern, using identically the same method.
O. F. Open Fire Heat Treatment.
S. B. Salt Bath.
P. P. Patent Process.
C. Cast.

130 cutters. Feeds, speeds, cutter design, deadline location, coolant, test logs, etc., have been varied until the conditions here set up permit us to evaluate within very close limits as noted, the cutting qualities of hardened high speed steel.

About four years ago the evaluating of high speed steel by means of the milling cutter test was started. At that time we tested commercially heat treated cutters hardened by patented processes, cast cutters and also the various types of high speed steel on the market, i. e., 18-4-1 type; 14-4-2 type; 18-4-1-Co; 18-4-1-Ur; hardened by ourselves in accordance with the recommendations of the various mills whose steels were being tested.

In a few words, the standard 18-4-1 type hardened by the open fire method and tempered to develop secondary hardness gave the most satisfactory all around performance.

Since that time questions have arisen in our minds as well as the minds of others as to the conclusiveness of the results. Consequently it was decided to run the present series of cutters to answer questions relative to hardening methods, forged high speed steel blanks versus bar stock, "breakdown" test versus "deadline test", variations caused by differing Brinell hardnesses in the test logs, variations caused by varying the cutting speed, effect of a supporting bracket for the overhanging arm of the milling machine, effect of varying amounts of coolant size and distribution of carbide nests, etc.

In our former test, it was noted that by arranging the photomicrographs of the hardened cutters in the order of the size of the cabide segregations, they automatically were arranged in the order of their cutting efficiency. The present series as shown by photomicrographs of samples taken from cutters 12 to 31 inclusive show a much better carbide distribution. Practically all of the leading cutters of this series show a much better structure than the best of the previous series and we have not been able to classify the cutting efficiency of the cutter by means of the microstructure.

Cutters 20 and 27 were hardened by the same concern using one set of prescribed conditions, i. e., steel, temperature, time, etc., and checked with 0.40 lineal feet. Cutters 13 and 11 were hardened by a different concern using another set of prescribed conditions and checked within 0.84 lineal feet. The ten cutters (10, 12, 14, 15, 16, 17, 18, 19, 22, and 24) were made from a selected steel

from the same source and hardened by various commercial hardening methods, i. e., salt baths, patented processes and open fire. The results obtained from these ten cutters varied considerably (Table I). However, cutters 12, 17, 22, and 24 were hardened under identical conditions by the same individual and the fact that they

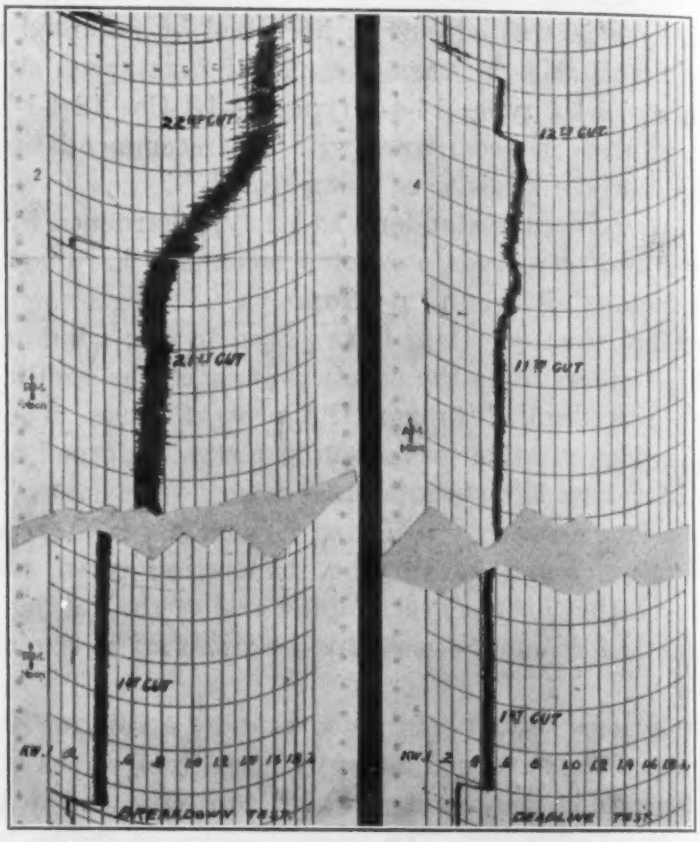


Fig. 4—Section of Autographic Records Showing a Comparison of the "Break-down" and "Deadline" tests.

ran within 0.56 lineal feet of each other when averaging three grinds coupled with the results previously obtained is indicative of the reliability of this testing method.

Cutter No. 24 was made from four inch round bar stock. Cutter No. 22 was a 2½-inch round bar upset to a 4-inch round blank. Both were normalized and annealed prior to machining the cutter. Both cutters gave identically the same performance, an exceptional check to be sure, but indicative of the fact that up to four inches round, a bar that has been reduced from an ingot in such manner as to be properly worked and refined should make as

good a cutting tool as a forged blank that has been upset to accomplish the same results.

After establishing the ratio of cutting efficiency between the various cutters under the prescribed conditions several were run at 169 revolutions per minute to evaluate the effect of the surface

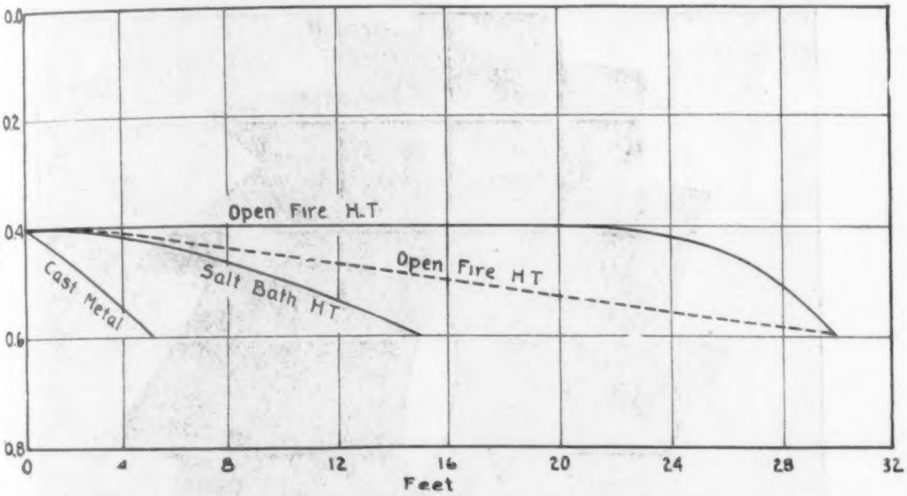


Fig. 5—A Graph Showing the Characteristics of 2 Open Fire Heat Treated Cutters, One Having the Ability to Hold a Sharp Keen Edge for the Removal of Many inches of Metal, while the Other Dulls Almost Immediately and Approaches the "Deadline" Gradually. A Salt Bath and Cast Metal Curve.

speed on the efficiency of the cutters. Those cutters that were best at 136 revolutions per minute were best at 16 revolutions per minute.

A supporting bracket for the overhanging arm of the milling machine failed to show any marked difference in the cutter's life.

One criticism leveled at our test was that the deadline which we set up mitigated against a cutter which has the tendency to dull rather quickly at the start but hangs on for a considerable period of time (refer to Fig. 5).

Cutter No. 27 which holds a keen edge and No. 28 which dulls at the start but hangs on, were ground for the fourth time and run to a breakdown (i. e., until they refused to remove metal; Fig. 4). Reference to Table I shows that the cutter comparison is better under the conditions which we have set up than when run to a breakdown.

The use of a recording wattmeter:

1. Indicates when the cutting edge begins to dull, thereby estab-

lishing the sharp keen edged tool from the one that turns over in a short time.

2. Indicates any irregularities that arise during the test as, rate

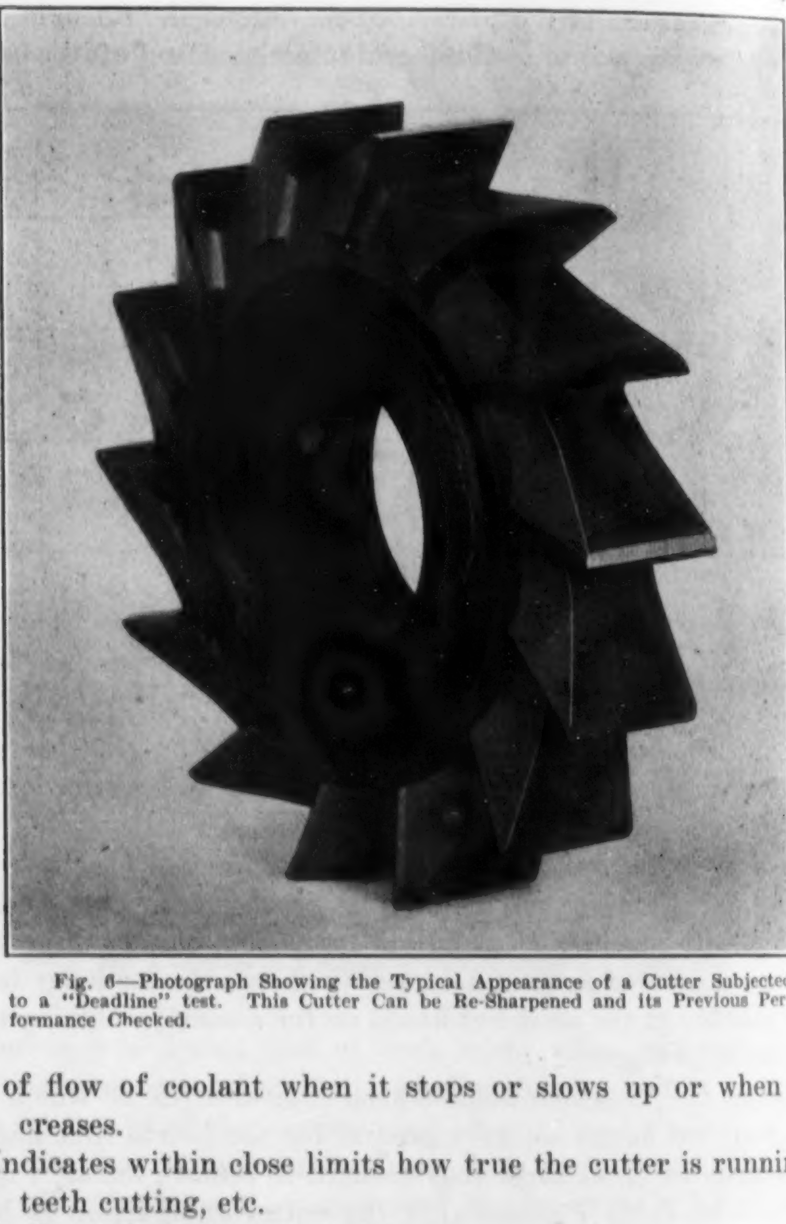


Fig. 6—Photograph Showing the Typical Appearance of a Cutter Subjected to a "Deadline" test. This Cutter Can be Re-Sharpened and its Previous Performance Checked.

of flow of coolant when it stops or slows up or when it increases.

3. Indicates within close limits how true the cutter is running, all teeth cutting, etc.
4. Indicates hard spots in test log.
5. Indicates when chips weld themselves to cutting face of the teeth.
6. Indicates when clearance is not sufficient for heel of the tooth to clear after three or four grinds.

7. Helps to promote care and attention to all details during the test. The operator soon learns that there is a reason for each

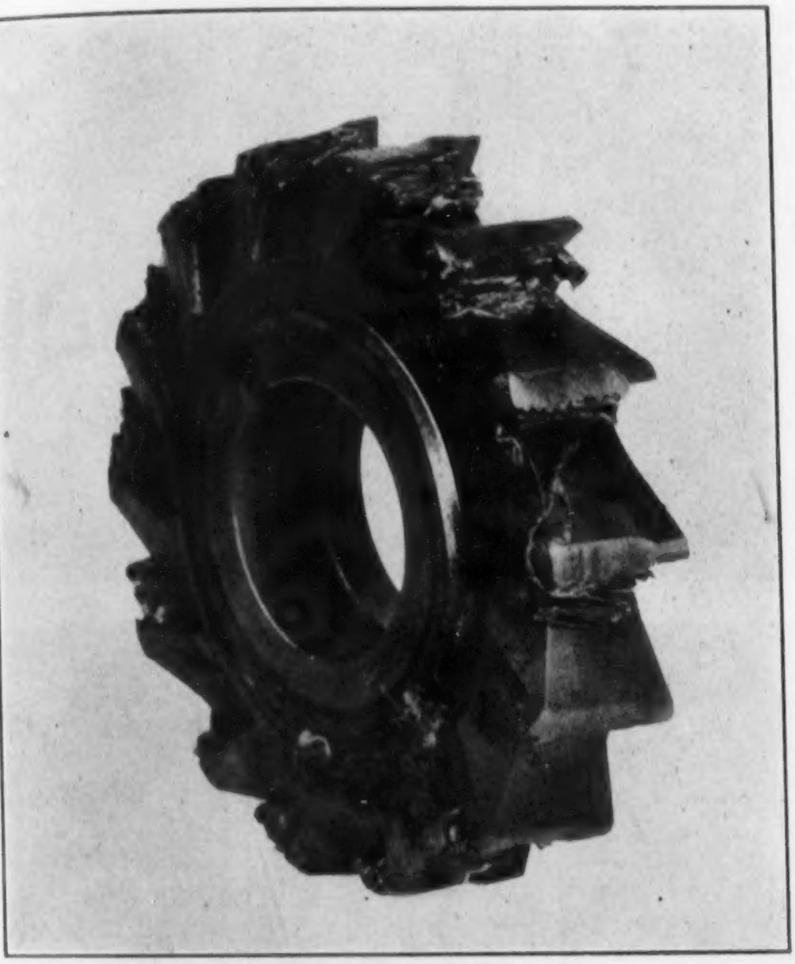
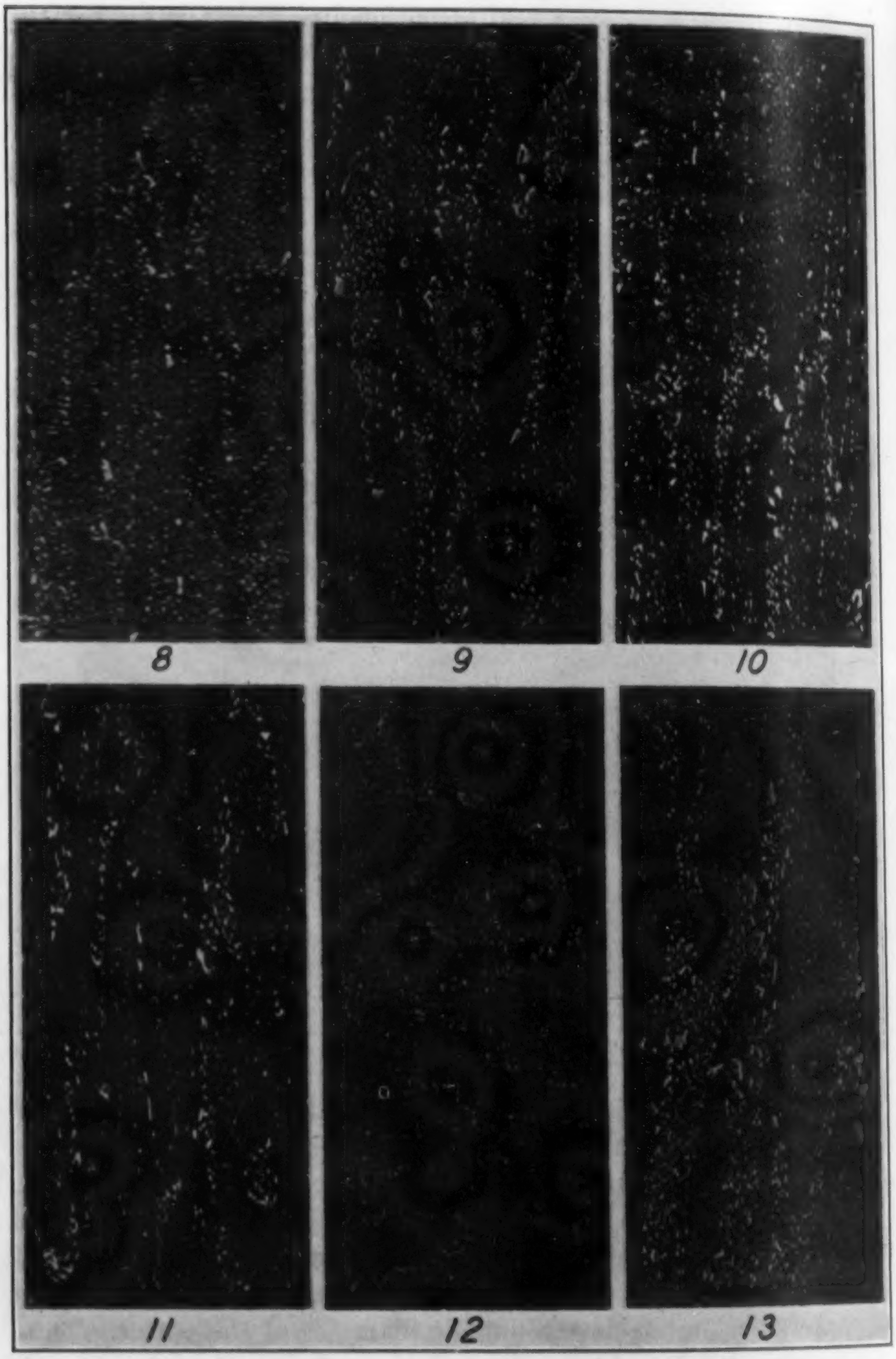


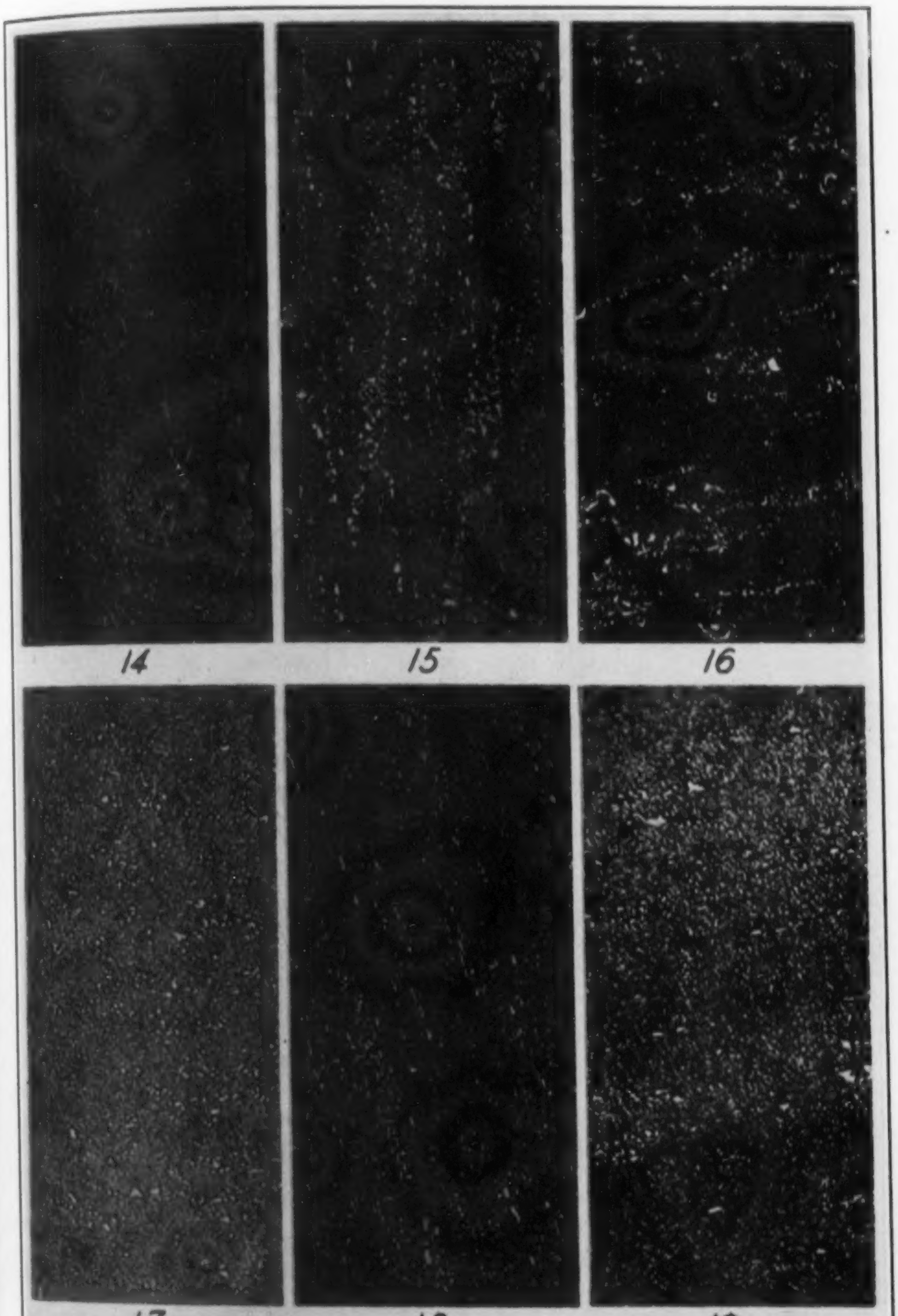
Fig. 7—Photograph Showing the Typical Appearance of a Cutter Subjected to a "Break-down" Test.

variation that shows on the chart and he is on the lookout for them.

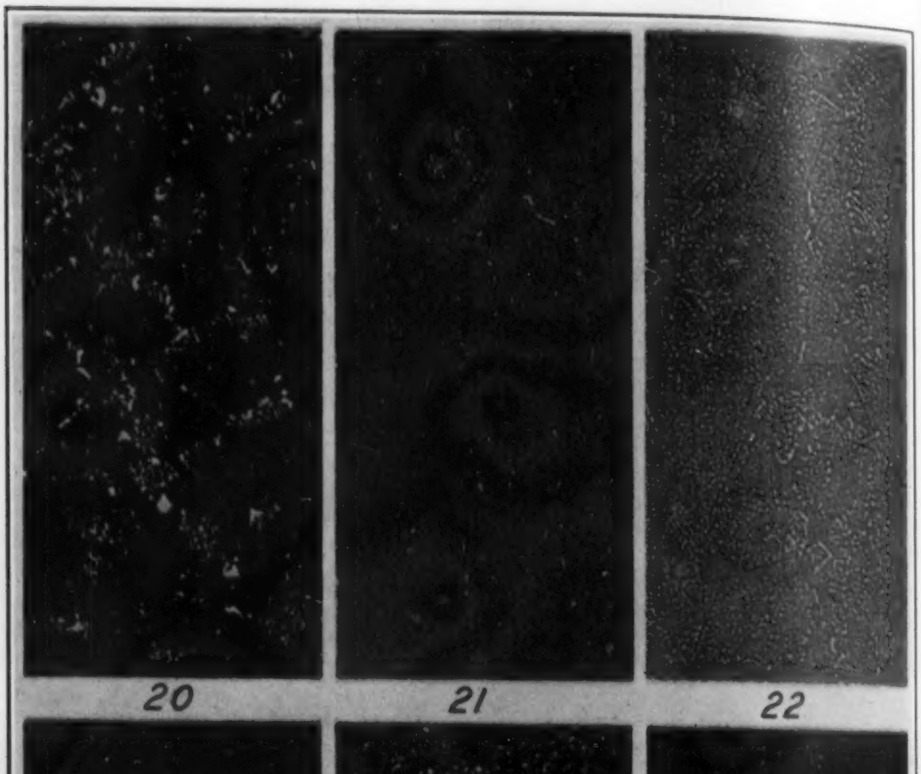
8. Makes a permanent record that can be referred to at some future date.
9. After the establishing of the deadline each cutter is dulled to a certain point (Fig. 6), then reground, by removing the same amount from the outside diameter of the cutter. Thus each cutter can be run several times for check purposes. A breakdown test would make rechecks of this kind impossible (Fig. 7).



Figs. 8 to 13—Photomicrographs of Milling Cutters Used in these Tests. Magnification 200 Diameters. These Photomicrographs Represent Samples 27, 20, 13, 12, 26 and 17 Respectively.



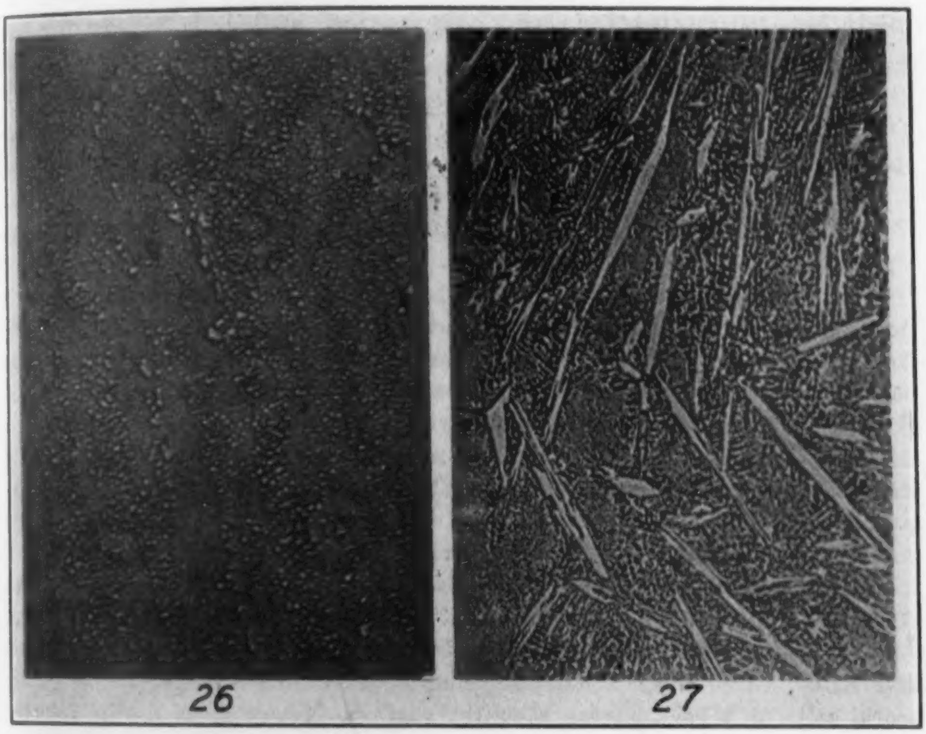
Figs. 14 to 19—Photomicrographs of Milling Cutters Used in these Tests. Magnification 200 Diameters. These Photomicrographs Represent Samples 22, 24, 23, 28, 15 and 25.



Figs. 20 to 25—Photomicrographs of Milling Cutters Used in these Tests. Magnification **200 Diameters. These Photomicrographs Represent Samples 31, 14, 16, 18, 29** and 19.

CONCLUSIONS

1. Cutters of the same steel hardened by the same method check within limits that are sufficiently close for test purposes.
2. No cast cutter has been found to give results comparable to standard high speed steel refined by suitable working.
3. Cutters hardened by patented or salt bath processes have not



Figs. 26 and 27—Photomicrographs of Milling Cutters Used in these Tests. Magnification 200 Diameters. These Photomicrographs Represent Samples 10 and 21.

given results comparable to standard high speed steel hardened by the open fire method.
4. In only a very few cases (refer to No. 26) has the cutting efficiency of the tools failed to increase from the first to the third, fourth, or fifth grind. The maximum cutting efficiency is generally reached by the third or fourth grind depending on the amount of metal removed per grind.
5. The question of low runs on the first two grinds of chemical analysis of high speed steel, and of hardening and tempering temperatures are items that are being investigated further.

Acknowledgement

The authors wish to express their indebtedness to W. Ruthven, assistant technical superintendent, who fostered early experiments in connection with these tests, and their appreciation for the suggestions presented by W. A. Scheuch, in charge of metallurgical development. They also wish to thank E. Shalla, milling section foreman, and A. Grant, assistant foreman of milling section, for their helpful suggestions and cooperation, and J. L. Gregg for the accompanying photomicrographs.

DISCUSSION

Written Discussion: By Jerome Strauss, U. S. Naval Gun Factory, Washington, D. C.

The emphasis which the authors have placed upon the mechanical engineering phases of their work is particularly significant. It is also gratifying to note that the design of the cutter and the method of testing both confirm the writer's own experiences during the past seven years as recorded in A. S. S. T. Data Sheets.[1] The writer's preference in respect to details of the design does not go to the extremes which the authors have used in constructing their cutters. The principles, however, are the same and have been carefully expounded by Oxford and Airey[2] in their excellent paper. The authors do not comment upon the method of failure of individual tools but presumably had any of the steels failed by breakage through the tooth, this would have been recorded. The lack of such failures is of special interest due to the fact that the cutter tooth possessed a plane back whereas the designs of Oxford and Airey, based upon the development of maximum strength in the cutter tooth, call for a back having a convex surface. For a given depth of tooth, of course, this feature becomes less important as the number of teeth for a given size cutter decreases.

The general method of testing employed is unquestionably the best for use in milling cutter tests, but it is surprising that such excellent checks between duplicate runs resulted under the specific conditions employed. The combination of the width (number of cuts) and length of the test block, the cutting speed and the cooling method made it necessary to cut away the ridges in the log surface at some time during most of the tests. This involved a notable time interval between two of the cuts. The lubricant appears to have been fed in such quantity that the temperature of the tool was at least a small contributing cause of failure and under such conditions it seems preferable not to have long time intervals between subsequent cuts. This may

[1]"Cutting Tests of Tool Steels," American Society for Steel Treating Data Sheet, by Jerome Strauss.

[2]"On the Art of Milling," J. Airey and C. J. Oxford, *Mechanical Engineering*, Vol. 43, 1921, page 549.

be secured by increasing the speed or increasing the width of the test log or both.

The authors refer to earlier tests with cutters of many different compositions, and from the metallurgical viewpoint the writer regrets that they have not included the results of some of these earlier tests in the present paper. It would be interesting and extremely valuable to have available the data of the test values and presumably the manufacturing characteristics as well, which led to standardization upon the high-tungsten, low-vanadium type of high speed steel.

The parallelism between carbide segregation and tool performance in the authors' earlier tests and the absence of such a relation in the present cutters, which are presumed to be relatively freer from segregation point to the possible existence of a degree of segregation above which (direction of lesser segregation) segregation is no longer the controlling factor in tool performance; this in turn, indicates a very simple method for the inspection of the raw material. It would appear that once the type composition and thermal treatment for a given class of service had been determined upon by a sufficient amount of direct testing, it would become merely necessary to specify this composition and to base inspection upon compliance with that requirement combined with some predetermined standards (real and not in the written word) of macro and microstructure which were available for examination by all producers interested in bidding upon the user's needs.

The writer would ask whether the authors observed the nature of the cutting edges after breakdown either under a hand glass or a low-power microscope, and, if so, whether any peculiarities were noted or any differences among different lots of steel or different type compositions.

J. B. Mudge: Mr. Chairman, the question of the design of the cutter tooth raised by Mr. Strauss, namely, the straight back as compared with the convex back can best be answered by the statement that only in one case have we broken a cutter tooth. That broke diagonally across the corner. This design of cutter is relatively inexpensive to make, and it has served our purpose and we can see no advantage in our tests in increasing the tooth strength by the use of the convex back. If we had had trouble with teeth breaking, naturally we would have had to strengthen the design by reinforcing the backs of the teeth. When you do that, you add metal at the expense of chip room and we prefer to stay with our present design as long as we do not run into any difficulties from that source.

We have observed the mechanics of the failure of the cutting teeth. When the sharply ground tooth begins to remove metal, the wire edge that is left by the grinding wheel will disappear after a short period and later small ridges appear perpendicular to the cutting edges of the teeth. As the cutter continues in service these small ridges get deeper and, if left too long, they round out as shown by this cutter, (exhibits large hollow in the cutter teeth). However, when running these cutters to a "deadline" we stop them for the most part before they get to that stage. As these ridges enlarge, the cutter tends to slide over the surface of the work and, one might say, work-harden the surface. This shows as a shiny streak or a number of streaks down the

length of the test log, and as soon as those shiny streaks appear in number the cutting tool fails rapidly. It is a burnishing action which very rapidly breaks down the cutting edge.

As far as the chemical analysis is concerned, we have observed no difference in the way the cutters fail.

Mr. Strauss pointed out the effect that heat has in breaking down the cutters. Heat unquestionably plays an important part in breaking down the cutters, but since all cutters are handled in relatively the same manner, we do not believe that it favors one cutter more than another and, furthermore, we are trying to keep this test as near shop conditions as we can, and not make it too empirical or of a laboratory nature.

The question of using the size and distribution of the carbide particles as a method of inspection is one which we would hesitate to grasp too quickly. I do not know at what stage of the game carbide segregation becomes objectionable. However, we do notice the tendency for lessening carbide segregation, but where the line should be drawn we are not in a position to say.

A. H. D'ARCAMBAL: The authors are to be congratulated on this splendid paper just presented. There are a few questions I would like to ask Mr. Mudge. I noted in one of the slides that the letters "S-B" appeared in the hardening column. Does that indicate "Salt Bath"?

J. B. MUDGE: Yes.

A. H. D'ARCAMBAL: That confirms our results; the salt bath treatment does not compare in any way with the open-fire treatment, when tools are used on production work.

J. B. MUDGE: We formerly made rather an exhaustive test of salt bath treated cutters, and it was found that they are, roughly speaking, about one-third to one-half as efficient as an open-fire-treated tool.

A. H. D'ARCAMBAL: The salt bath treated cutters were tempered in the same manner, I suppose, as in the open-fire treatment.

J. B. MUDGE: Yes, after the quench. Understand, I am not referring to any patented processes or any commercial process. Our salt bath hardening method is: preheat in an open-fire furnace to about 1700 degrees Fahr., then put the tool in a molten salt bath, the temperature of which is approximately 2200 degrees Fahr., hold until heated through, then quench into a molten salt bath the temperature of which is approximately 1050 degrees Fahr., and when the tool and bath have equalized, the tool is removed and allowed to cool to room temperature, in the open air. Subsequently the tool is tempered at 1050 to 1100 degrees Fahr. in an electric muffle furnace.

A. H. D'ARCAMBAL: Did you try pack-hardening any cutters in this test?

J. B. MUDGE: No.

A. H. D'ARCAMBAL: Were some of the patented process treated in that manner?

J. B. MUDGE: I do not know; I believe in one or two cases they were, although we have not been informed to that extent. I do not know what methods were used in many of the cases of commercial hardening.

A. H. D'ARCAMBAL: In a test we ran some years ago, we found that cut-

ters pack-hardened gave much inferior results to tools given the open-fire high tempering treatment.

J. B. Mudge: Have you observed a tendency for an inferior cutting performance on the first cut with the pack-hardened cutters?

A. H. d'Arcambal: Yes, we did, and it became more inferior as the cutters were reground.

J. B. Mudge: It had occurred to us that perhaps the reason for this gradation from the first to the third cut is due to the fact that some of the carbon is burned out in the high heat and it is not until you get well under the cutting surface that you get to the normal structure.

A. H. d'Arcambal: We believe that when a diameter of four inches is reached for any type of cutters, it is advisable to use forged blanks. At three and one-half inches we have not noticed very much difference, but in a test conducted some years ago we found the cutters four inches in diameter made from forged blanks gave about twenty-five per cent greater life than cutters made from bar stock; moreover that fractures on the forged blank cutters were much more velvety in appearance and showed less segregation under the microscope. We also found that better cutters resulted when the forged blanks were made by heating a billet and then squashing down the end of the same cutting off the section and rounding it up, etc., rather than taking a smaller piece and up-setting it. We have tried the latter method and it does not improve the grain or the microstructure much over bar stock.

The question of lubricant is certainly important. We have been in a large number of shops around the country where the cutter life has been greatly increased by either increasing the amount of lubricant or changing the type of lubricant being used. I was very glad to see that point brought out.

I would like to ask Mr. Mudge if he has tried chromium plating cutters, then conducting these tests on them?

J. B. Mudge: No, we have not.

A. H. d'Arcambal: We have conducted experiments along these lines finding that chromium plating does not increase the cutter life. It may be, of course, that the cutters were not correctly hardened.

J. B. Mudge: We have noticed the tendency toward a marked decrease in the carbide segregation in high speed steel. May I ask the representatives of the steel makers whether any recent changes in mill practice would account for this, i. e., the size of ingots, the method of hammering, etc.

Chairman J. A. Mathews: I would say a combination of circumstances and temperature control also.

ARMCO INGOT IRON

By Reid L. Kenyon

Abstract

Armco ingot iron is the trade name for commercially pure iron produced in the basic open-hearth furnace. The product has now been on the market for several years and has become useful in many industries. Due to its high degree purity it has been used in many scientific investigations where pure iron has been required.

References to Armco ingot iron or "Armco Iron," in the literature are many. It has been tested and experimented upon in all manner of ways, but no attempt has yet been made to compile and coordinate the vast amount of data that has accumulated from the work of various investigators upon this material. In addition to references to published results of various investigators, this paper also presents numerous data from unpublished work of the research department of the American Rolling Mill Company.

The scope of the paper includes a description of the material, its chemical analysis, its microstructure after various treatments and the effect of mechanical work and heat treatment on its various physical properties. This data is given for Armco ingot iron in the form of hot-rolled and cold-rolled bars and shapes, plates, sheets, and wire. The tests reported include tension, compression, shearing, impact, hardness, and fatigue tests of various kinds.

ARMCO ingot iron is the trade name for commercially pure iron produced by the basic open-hearth process. It has now been on the market for a number of years and has found a long list of uses. On account of its high degree of purity it has been used in many scientific investigations where pure iron, especially in large quantities, was required.

References to Armco ingot iron or "Armco Iron" in the literature are legion. It has been tested and experimented upon in all manner of ways, but as far as the author is aware no at-

This paper is based on a thesis submitted by Reid L. Kenyon in partial fulfillment of the requirements of Purdue University for the degree of Chemical Engineer, June, 1927.

A paper presented before the ninth annual convention of the Society held in Detroit, September 19 to 23, 1927. The author, R. L. Kenyon is research associate, American Rolling Mill Co., Middletown, Ohio.

tempt has yet been made to compile and coordinate the vast amount of data that has accumulated from the work of various investigators upon this most useful and important material. In addition to references to published results of various investigators, this paper also presents numerous data from unpublished work of the research department of the American Rolling Mill Company.

It was in 1911 that the first announcement (1)[1] was made before a scientific and technical society that the manufacture of commercially pure iron in a basic open-hearth furnace had been successfully accomplished. The following is quoted from an abstract of the paper (2) which was published in the Journal of the British Iron and Steel Institute of the same year.

> "* * * It differs from steel in many particulars, especially in its freedom from manganese. * * * The material is of such a nature to challenge once again, all definitions hitherto proposed for the differentiation of iron and steel and further to confuse the nomenclature.
>
> "In conjunction with the results of chemical analysis, the microscope now serves as a means of enabling the metallurgist to distinguish iron from steel and has gradually led to iron being regarded as a name applicable only to products which show slag inclusions under the microscope. Steel from the very nature of its manufacture does not exhibit this peculiarity and it is not surprising, therefore, that the mere presence or absence of slag should gradually have come to be held as the distinguishing characteristic between steel and iron. From the modern standpoint neither the presence or absence of slag can, however, be held to settle the matter of nomenclature, excepting that the presence of slag inevitably points to the process by which the material was prepared. From a perfectly reasonable standpoint it would appear that after the carbon-iron alloy field has been eliminated, the nearer the metal approaches the theoretical constitution of the element itself, the more it justifies the name of iron."

Several years ago there was considerable discussion on this question of what is iron and what is steel, and some contended that any ferrous metal of molten origin was "steel"; that "iron" was necessarily of plastic origin. This view of the matter has

[1]The figures appearing in parentheses refer to the bibliography appended to this paper

long since been discredited by the same line of reasoning as that in the above quotation.

Method of Manufacture—The manufacture of Armco ingot iron is carried out in the basic open-hearth furnace (3). The manipulation is similar in many respects to that used for making mild steel. The main point of difference is that the refining operation is carried further in making a heat of ingot iron, thus reducing all impurities to the minimum. This is accomplished by adding iron ore to the bath which oxidizes the silicon, phosphorus and carbon. A highly basic slag reacts with the products of oxidation thus effecting their more or less complete removal from the bath (4).

As the impurities are removed during the refining period, the melting point of the metal is raised and it is therefore necessary to operate the furnace at a considerably higher temperature when making ingot iron heats than for mild steel. This of course results in shortening the life of the furnace refractories and auxiliary equipment. Not only is it necessary to operate the furnace at higher temperature but for longer periods of time because the refining operation has to be carried further to bring down the impurities to the minimum necessary for Armco ingot iron.

Chemical Analysis—As has been stated, this material is commercially pure iron. The manufacturers guarantee a maximum of 0.16 per cent impurities, considering the elements, carbon, manganese, phosphorus, sulphur and silicon. The high purity of this material is well substantiated by the fact that the Bureau of Standards has chosen it for a "standard sample" of ingot iron. A typical analysis of Armco ingot iron is as follows:

	Per Cent
Carbon (combustion)	0.013
Manganese	0.017
Phosphorus	0.005
Sulphur	0.025
Silicon	Trace
Total	0.059
Iron by difference	99.941

Uses—Armco ingot iron was developed originally as a rust resisting material manufactured into sheets. It has therefore been widely used wherever sheet metal has had to withstand unusual corrosion-promoting conditions. In sheet form it has been

galvanized for roofing and siding of barns and industrial buildings, and gutters and downspouts on both industrial buildings and residences. It is also used for tanks and smokestacks of all kinds. Another wide field has been the corrugated culvert for drainage purposes.

As time went on it was found that this metal had other outstanding properties. Its high purity and freedom from gases made it well suited for oxyacetylene and electric arc welding, both as material to be welded and as welding rods (5) (6). Another important field for Armco ingot iron has been in the form of sheets for vitreous enameling. Thorough degasification of the metal plays an important part here again in minimizing bubbles, blisters and other enamel defects.

In the form of plates it is used for gas holders, stand-pipes and other large tanks. The electrical resistance is considerably lower than for mild steel and it has therefore been used for telegraph wire and bond wire for rail signal circuits for railroads. Its high magnetic permeability and low retentivity has stimulated its use for solenoid plungers, magnet cores and other parts of electrical equipment.

In addition to these specific uses of the material in various finished forms, its intrinsic purity has made it a suitable raw material for various other products. For example, some manufacturers of high grade tool steel use Armco ingot iron for melting stock because of its high degree of purity and its availability in commercial quantities. It is a favorite material with various investigators for the preparation of various ferrous alloys.

These uses are only a few out of many and are mentioned here because they typify the peculiar properties of this material which make it suitable for these various applications. It might be said in passing that specific recognition of these properties of Armco ingot iron was shown in the Grand Prize awarded to it at the Panama-Pacific Exposition for its superior enameling, welding, electrical, magnetic and corrosion-resistant properties.

Microscopic Study

Microstructure—When a sample of iron of high purity such as Armco ingot iron, is suitably prepared and examined under the microscope, it exhibits a network of grain boundaries such as that shown in Fig. 1. This appearance is the result of a slight

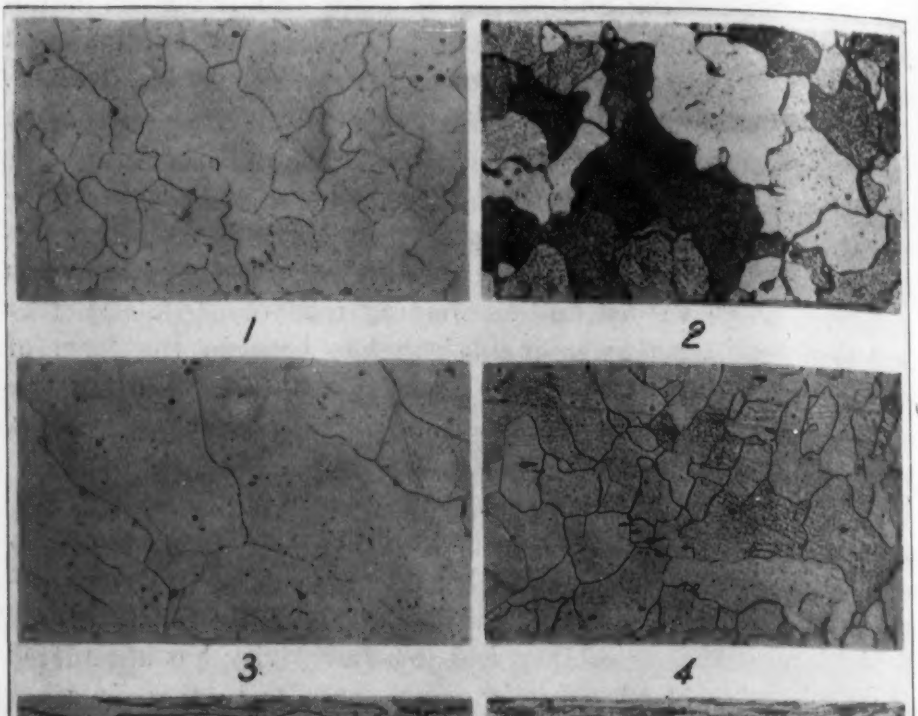


Fig. 1—Photomicrographs of Armco Ingot Iron Etched Lightly to Show Grain Boundaries. Fig. 2—Etched Deeply to Show Orientation. Fig. 3—As Cast. Fig. 4—Hot-Worked. Fig. 5—Cold-Worked. Fig. 6—Excessively Cold-Worked. Fig. 7—Cold-Worked and Annealed. Before Annealing this had a Structure Similar to Fig. 5. Fig. 8—Annealed After Excessive Cold Working. Before Annealing this had a Structure Similar to Fig. 6. Note: All specimens were etched in 3 per cent nital. Magnification 100x.

etching of the polished surface with a dilute alcoholic solution of nitric acid. If this etching is continued for a longer time a dis similarity between different grains will be observed as shown in Fig. 2. These two photomicrographs were taken of exactly the same spot on the sample after different degrees of etching. By comparing the two pictures, it will be seen that the grains that have darkened on longer etching, showed no difference from the others when only etched for a short time. These two photomicrographs are presented as evidence that there is no difference in chemical composition between the different grains. As a matter of fact, it is generally accepted that this apparent difference in shade brought about by longer etching is due to a difference in orientation of the crystalline structure within the different grains and not to any difference in chemical composition (7).

From theoretical considerations it is believed that pure iron, like other pure metals, solidifies in the form of dendrites. The etching reagents used to develop the structure of metals and alloys fail, however, to reveal the presence of dendrites in pure iron, probably because of the high degree of homogeneity which gives no opportunity for the selective action of the reagents to function. It is thought by some that the dendrites are actually formed during solidification but that they are subsequently "granulated" during cooling and are broken up into grains of gamma iron. The latter undergo a further transformation at about 1650 degrees Fahr. (900 degrees Cent.) into alpha iron which results in the final structure that is observed under the microscope.

For the reasons just given, a sample of Armco ingot iron in the cast condition shows "micro-grains" when observed under the microscope. These grains are somewhat irregular in shape but otherwise they do not differ materially from those of the same material after working and annealing. The structure of cast Armco ingot iron is shown in Fig. 3. The positive assertion cannot be made, however, that the dendrites may not still exist although they cannot be identified by any known etching method. It is possible that the grains visible under the microscope are only subdivisions of the larger dendrites whose boundaries are "camouflaged" by the network of smaller grains.

When the cast material is heated to some temperature above 1650 degrees Fahr. (900 degrees Cent.) and rolled, forged, drawn, or pressed it is said to have been "hot-worked." If the working is

continued until the piece becomes cold or is resumed again after the piece has cooled, it is then called "cold working." These two different methods of working and all variations between the two extremes will result in various microstructures. The structure of "hot-worked" Armco ingot iron is shown in Fig. 4 and the "cold-worked" material in Fig. 5. An excessive amount of cold working, as in the case of cold drawn wire, will produce a structure similar to that shown in Fig. 6.

The effect of annealing cold-worked Armco ingot iron will be discussed later, but reference is here made to Fig. 7, which shows the structure produced by annealing a cold-worked piece which, before this annealing, had the structure shown in Fig. 5. Fig. 8 shows the structure after annealing of a severely cold drawn Armco ingot iron wire which had the structure shown in Fig. 6 before it was annealed. The amount of cold working strains and the temperature at which they were produced as well as the time and temperature of the annealing all affect the final grain size. These variables account for the difference between Figs. 7 and 8. The structure shown in Fig. 7 is that of a well-annealed piece of Armco ingot iron sheet.

Physical Properties

General—Inasmuch as the purity of Armco ingot iron is very high it is to be supposed that its physical properties will closely approximate those of the element iron. As a matter of fact this is actually the case. In the following discussion, where possible, the results on electrolytic iron will be given also for the purpose of comparison.

Specific Gravity—The specific gravity or density of annealed Armco ingot iron has been given by O'Neil (8) as 7.8580. This investigator has also studied the effect of cold work upon this property. In the paper just referred to he reports the results of careful density determinations on small pieces cut from different portions of a tensile test specimen in which the elongation varied in different parts.

These results are also shown in Fig. 9. It will thus be seen that the effect of cold working is to reduce the density. This may be explained by the fact that cold working produces amorphous material which has a lower density than the crystalline phase and

so lowers the density of the aggregate. In the case of the cold rolling of sheets the reductions are seldom carried beyond 2 or 3 per cent and therefore the density of such material is not affected in this manner.

The weight tables for sheet metal found in various hand books are based on the U. S. Standard gage which was legalized by Act of Congress. These tables for iron and steel are based on hot-rolled

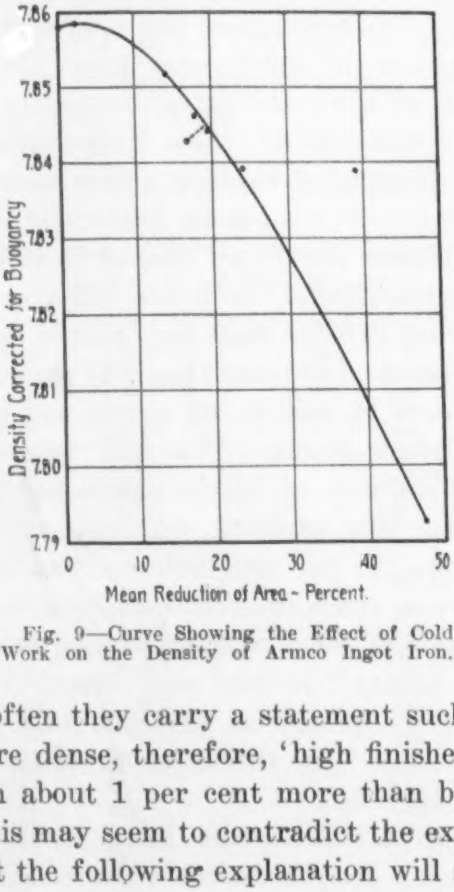


Fig. 9—Curve Showing the Effect of Cold Work on the Density of Armco Ingot Iron.

sheets but very often they carry a statement such as "cold rolling makes sheets more dense, therefore, 'high finished' or 'cold-rolled' sheets will weigh about 1 per cent more than black sheets of the same gage." This may seem to contradict the experimental results quoted above but the following explanation will show that there is no contradiction.

At the outset it will be necessary to define several terms. "Density" in the physical sense means "weight per unit volume," but the term is applied loosely in the sheet industry to describe the appearance of the surface of sheets. A "dense" surface is one free from "scale-matt," "pits," or other similar surface imperfections. As cold rolling will minimize such defects it may be said in this sense that cold rolling makes a "denser" sheet. But this is only intended to be descriptive of a surface condition.

As far as weight per unit volume is concerned, it is also true that this value as ordinarily determined will be increased by cold rolling a black sheet. When such a determination of density is made the length and width of the sheet can be measured quite accurately with a rule or steel tape but the micrometer is the only means of measuring the thickness. A "black sheet" will have numerous, almost microscopic irregularities in its surface which are flattened out by cold rolling. When the thickness of a black sheet is measured the reading of the micrometer is greater than it should be because the micrometer gives the distance between the tops of some of the small irregularities on opposite sides of the sheet. After cold rolling, these irregularities are greatly reduced and the micrometer reading comes nearer being the true thickness. In other words it is impossible with an ordinary micrometer to measure the "true" thickness of a black sheet.

Surface irregularities of the metal will always cause the readings to be somewhat greater than they should be. The amount of this error will depend on the smoothness of the surface and for this reason the thickness of cold-rolled sheets can be measured more accurately than black sheets. This will result in the apparent weight per unit volume of black sheets being lower than the "true" value and this explains why cold-rolled sheets have a higher apparent weight per unit volume than black sheets. It is necessary to have a clear understanding of the reason for this difference in weight of black and cold-rolled sheets. As has been said, the term "density" is used very loosely and the facts just given are frequently quoted as evidence that cold rolling does increase the "density" of sheets (both surface condition and weight per unit volume).

The foregoing statements are based upon a series of tests (9) in which density determinations were made on samples taken from the same sheet before and after cold rolling. A 20-gage black sheet 24 x 113 inches was chosen for the test and a piece 30 inches long was cut from one end to furnish samples of the material in this condition. The rest of the sheet was given two passes in the cold rolls and a second 30-inch long piece cut from it and the remaining portion given ten more passes in the cold rolls. The two passes produced a reduction in thickness of 5.4 per cent while the additional ten passes increased this to 12.6 per cent based on the original thickness.

Six samples 3 x 5 inches were cut from the center of each of the three sections of the sheet. Small pieces were used in order to permit weighing on accurate balances and also to reduce the variation in gage which would be less on small samples. The gage of each sample was read at fifteen different places at uniform intervals over the sample. Readings were made to four decimal places and the average of the fifteen readings taken as the mean thickness of the sample. The lengths and widths were measured with an accuracy of 0.01 inch. The samples were weighed to the nearest milligram on an analytical balance. The values for each of the samples are given in Table I.

Table I
Effect of Cold Rolling on the Weight Per Unit Area of Armco Ingot Iron Sheets

Condition	Samp No.	Thickness, Av. at 15 points	Wt. in Grams	Area of Samp. Sq. In.	Wt. Grams per Cu. Inch.	Density Grams per cc.	Wt. based on thickness of 0.0375" in #/sq. ft.
Blk	1	0.0384"	72.971	14.94	127.2		1.516
	2	0.0384	73.114		127.4		1.518
	3	0.0388	73.869		127.4		1.518
	4	0.0391	74.231		127.1		1.515
	5	0.0391	74.566		127.6		1.520
	6	0.0396	74.964		126.7		1.522
	Av.	0.0390"			127.23	7.764	1.518
2 Pass Cold-Rolled	21	0.0372"	72.006	14.94	129.6		1.545
	22	0.0372	71.506		128.7		1.535
	23	0.0368	71.150		129.4		1.543
	24	0.0367	70.987		129.3		1.542
	25	0.0367	70.979		129.3		1.542
	26	0.0366	70.889		129.6		1.545
	Av.	0.0369"			129.32	7.892	1.542
12 Pass Cold-Rolled	31	0.0342"	66.260	14.94	129.7		1.546
	32	0.0342	66.129		129.4		1.543
	33	0.0341	66.097		129.7		1.546
	34	0.0341	66.150	15.00	129.7		1.546
	35	0.0340	65.927		129.3		1.542
	36	0.0339	65.676		129.3		1.542
	Av.	0.0341"			129.52	7.904	1.544

The weight in pounds per square foot given in the last column of Table I is based on a uniform thickness of 0.0375 inches in order to make it possible to compare the three sets of tests on a common basis. These figures show the cold-rolled material to have a higher weight per unit area (for the same thickness) than the black sheet.

This difference in weight per unit area of black and cold-

rolled material is due to discrepancies inevitably arising in measuring the thickness of the black sheets. This has already been discussed. If cold rolling actually increased the "true weight per unit volume" by "compressing more metal" into a given volume the 12-pass material would show a greater increase over the 2-pass sheets than it does. The big difference is between the black sheets and the same after two passes in the cold rolls.

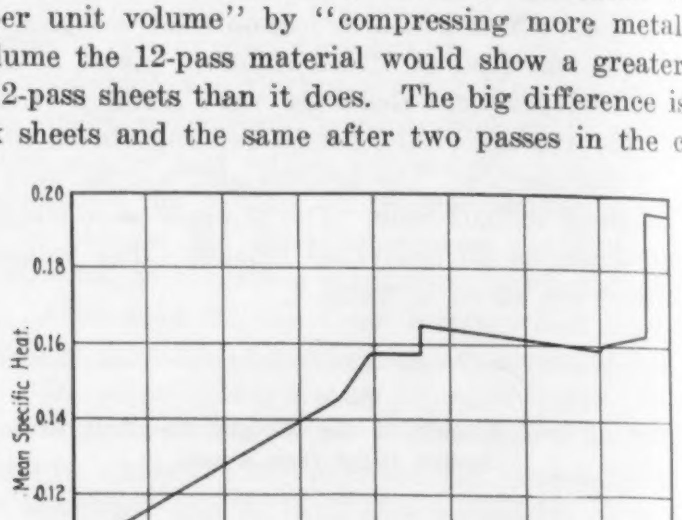


Fig. 10—Curve Showing the Mean Specific Heat of Pure Iron in Relation to Temperature. (Oberhoffer.)

These two passes seem to remove all the "high and low" spots that can be removed by cold rolling, for ten additional passes produced no further change.

From these tests it will be seen that cold-rolled sheets will show more weight per unit area than black sheets that micrometer the same gage, but this is due solely to the impossibility of accurately measuring the "true" thickness of a black sheet with a micrometer. As the micrometer is the only practical means of measuring the thickness of sheets in production and is the means commonly used, it is correct to say that a cold-rolled sheet will weigh more per unit area than a black sheet of the same gage, but it should be remembered that the difference in density is only "apparent" and is due to the natural limitations of the measuring equipment.

Specific Heat—The research laboratory of the American Rolling Mill Company has made no accurate determinations of the specific heat of Armco ingot iron and as far as our search of the literature has gone we have been unable to find any published re-

sults of other investigators on the determination of this quantity for Armco ingot iron. Because of the close approximation of other fundamental properties of Armco ingot iron to those of electrolytic or other specially prepared pure iron samples, reference will be made to the work of Durrer quoted by Oberhoffer (10). These determinations were made on iron which was said to be "very nearly pure." The curve given in Oberhoffer, "Das Schmiedbare Eisen" is reproduced in Fig. 10.

Heat Conductivity—The heat conductivity varies with the temperature. The results given here are for room temperature. Careful determination of this quantity (11) for Armco ingot iron gave the value of 0.16 calories per second per square centimeter per centimeter thickness per degree Cent. of temperature difference. This checks closely with the result given by Kent (12) for "pure iron" at 64 degrees Fahr. This value is, 0.161 calories per second per square centimeter per centimeter thickness per degree Cent. of temperature difference (13). It might be of interest to note that both of these sources give 0.14 C. G. S. units for wrought iron.

Electrical Conductivity—Very careful tests have been made (14) on the electrical conductivity of Armco ingot iron. On the basis of these tests the following values are given for normalized Armco ingot iron tested at 71 degrees Fahr. (21.6 degrees Cent.).

Resistivity	4.0747 microhms per inch cube
Conductivity	16.78 per cent Volumetric basis
(Matthiessen's Std)	18.98 per cent Weight basis
Conductivity	16.76 per cent Volumetric basis
(International Std)	18.96 per cent Weight basis

Magnetic Properties—The high magnetic permeability at high inductions and low retentivity of Armco ingot iron recommend it for a number of electrical uses such as magnet armatures and solenoid plungers where a maximum pull must be obtained with a given number of ampere turns and a quick release effected when the magnetizing force is removed.

The magnetic properties are affected by mechanical working and heat treatment. The best magnetic properties are obtained by annealing at a maximum soaking temperature of approximately 1400 degrees Fahr. and slowly cooling. The accompanying curves (15) are representative of the magnetic properties of Armco ingot iron after this heat treatment.

Fig. 11 shows the normal induction curve for Armco ingot iron. It shows the flux density (B) in gausses produced by magnetizing forces (H) in the same units. Values of permeability

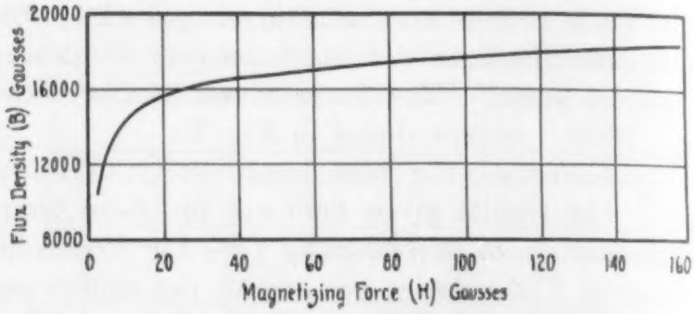


Fig. 11—Normal Induction Curve for Annealed Armco Ingot Iron.

may be computed from the curve at any desired point. The hysteresis curve is shown in Fig. 12 from which the retentivity and coercive force may be computed.

Coefficient of Expansion—This fundamental property has

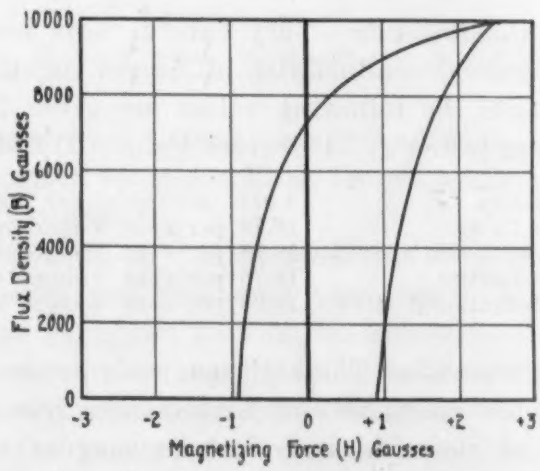


Fig. 12—Hysteresis Curve for Annealed Armco Ingot Iron.

been accurately determined (16) for Armco ingot iron with the following results:

Temperature Range Degrees Cent.	Average coefficient of expansion
20-300	0.0000129
20-600	0.0000147
20-900	0.0000147

For comparison it is interesting to note that the same laboratory reports (17) the following values for electrolytic iron.

Temperature Range Degrees Cent.	Average coefficient of expansion
25-300	0.0000133
25-600	0.0000147

This again illustrates the close argeement between the properties of the commercially pure Armco ingot iron and electrolytic

Table II
Melting Point of Pure Iron

Melting Point Degrees Centigrade	Melting Point Degrees Fahrenheit	Reference
1535	2795*	(64)†
1530	2786	(65)
1535	2795	(66)
1530	2786	(67)
1530	2786	(68)
1528	2782	(69)

*The Fahrenheit temperatures are obtained by conversion from the Centigrade values.
†See references appended to this paper.

Table III
Boiling Point of Pure Iron

Boiling Point Degrees Centigrade	Boiling Point Degrees Fahrenheit	Reference
3000	5432*	(70)†
2450	4442	(71)
2450	4442	(72)
2450	4442	(73)
2450	4442	(74)

*The Fahrenheit temperatures are obtained by conversion from the Centigrade values.
†See references appended to this paper.

iron of special purity prepared on a small scale by careful laboratory refining methods.

Melting Point—The melting point of iron-carbon alloys increases with decreasing carbon content. As the carbon content of Armco ingot iron is only 0.010 to 0.015 per cent it may be considered to be pure iron as far as the melting point is concerned.

The results given here are taken from various sources and are for electrolytic iron or other specially prepared iron of high purity.

Boiling Point—The boiling point of iron has been determined and is reported in the literature. While these determinations are on electrolytic iron or other specially prepared pure iron the values given may be assumed to be correct for Armco ingot iron on account of the very close similarity in analysis.

Tensile Properties

General—It is well known that the size and shape of the test piece have a marked effect on some of the quantities determined in the tensile test. From the results of a large amount of data collected by numerous investigators, it is possible to make certain generalizations on the effect of these variables. It is the intention to discuss these points briefly before going into a detailed study of the physical properties of Armco ingot iron.

It has been shown by various investigators (18) (19) (20) that so long as test specimens of a given material are geometrically similar; the tensile strength, yield point, percentage elongation, and percentage reduction of area remain constant. (21) (22) (23). As a matter of fact the percentage elongation is the one quantity which is affected most noticeably by variations in the proportions of the test piece, but even this value may be made comparable for a wide variation in dimensions if the law of similarity is adhered to.

It is true that various scientific societies such as the American Society for Testing Materials have standardized certain tensile test samples but except in the case of cylindrical specimens (0.505-inch round, 2-inch gage length), the proportions are somewhat variable. This is especially true in the case of plate and sheet material. Although a standard length and width have been set for plate specimens (24), the material is tested in its original thickness which introduces a variable in the cross sectional area-gage length ratio.

In the case of sheet metal the variable of thickness is especially influential upon the percentage elongation results. Although it is theoretically possible to obtain comparable elongation values on material of different thicknesses by varying the width of the specimen to keep a constant cross sectional area, there are certain practical difficulties in the way. A committee of the

American Society for Testing Materials has surveyed this problem in a broad way and has reported its findings (25).

While this committee did not deem it wise to recommend a standard specimen for sheet metal without further consideration and discussion, it states in its report that a survey of about forty

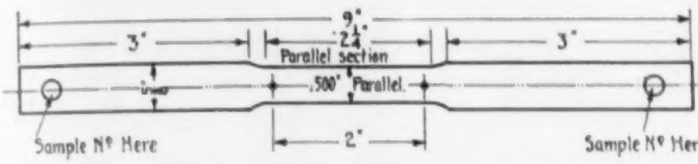


Fig. 13—Revised Standard Test Piece No. 3. Note: This shape test piece is used for all metal that is light enough to be tested in the special sheet testing grips. All burrs are removed from the edges.

leading laboratories making tests of this kind showed a larger number used a ½-inch wide 2-inch gage length specimen than any other one type. This is the type which is used for all tests on 13 U. S. gage and lighter material reported in this paper. Fig. 13 shows a sketch of this test piece. It will be noted that this drawing calls for a parallel gage length which does not taper at

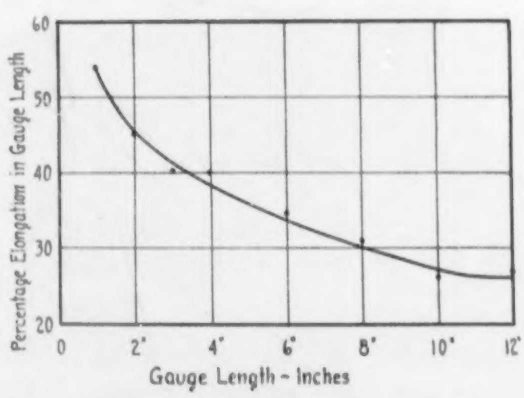


Fig. 14—Curve Showing Effect of Gage Length on the Per Cent Elongation of Armco Ingot Iron.

the middle. This is contrary to the practice followed by many investigators but after a thorough trial of the tapered sample we have discarded it. When the samples taper so as to be 0.003 to 0.004 inch narrower at the center of the gage length, the idea is to make the fracture occur near the middle of the gage length. The cross section is naturally measured at the narrowest point. The difficulty with the tapered specimen is that the fracture frequently occurs at some other point and then the exact unit stress at the

point of fracture cannot be determined because the original cross section at that point is not known. By making the shoulders only 0.025 inch on each side, the concentration of stress at this point has been minimized and very few specimens break outside of the gage length.

Effect of Gage Length on Percentage Elongation—The effect of gage length on the elongation is well understood in general and various investigators have published results of tests on samples of steel with constant cross section and variable length (26) (27).

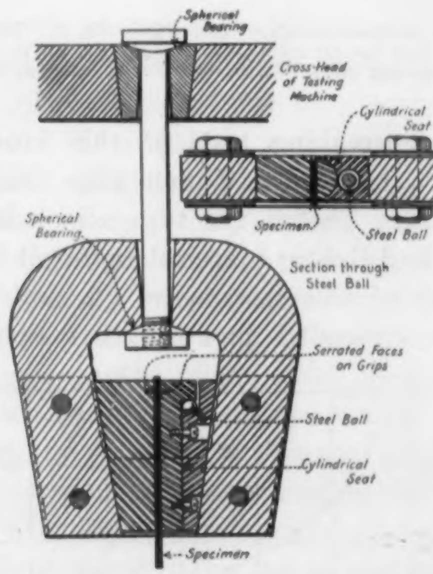


Fig. 15—Diagrammatic Sketch of Special Grips for Tensile Tests on Sheet Metal. From A. S. T. M. 1925, II Tentative Standards, page 858.

The average amount of elongation per inch of gage length of course decreases as the gage length increases. This is due to the "necking-in" effect which occurs at the point of fracture of ductile materials when tested in tension.

As Swain (28) gives it, "the percentage elongation $= 100\frac{\lambda}{L}$

The elongation λ is made up of two parts, one a general elongation approximately uniform over the length L and therefore proportional to L, and independent of the sectional area, and the other a local elongation due to the necking, and independent of L but increasing with the sectional area."

In order to determine (29) the effect of gage length on per-

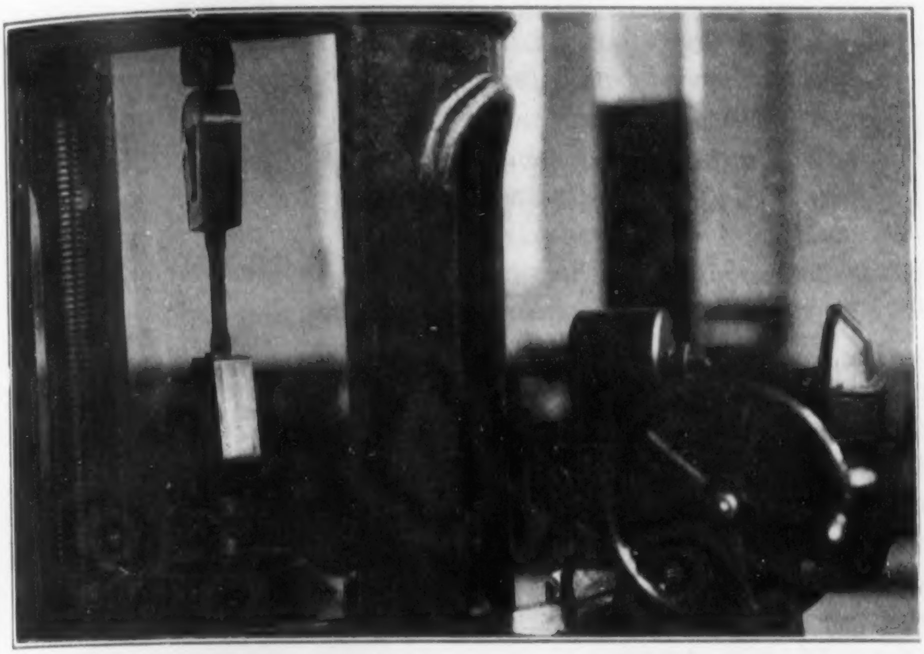


Fig. 16—Special Grips for Holding Sheet Specimens for Tensile Test. Photograph Shows the Grips in Place in the Machine.

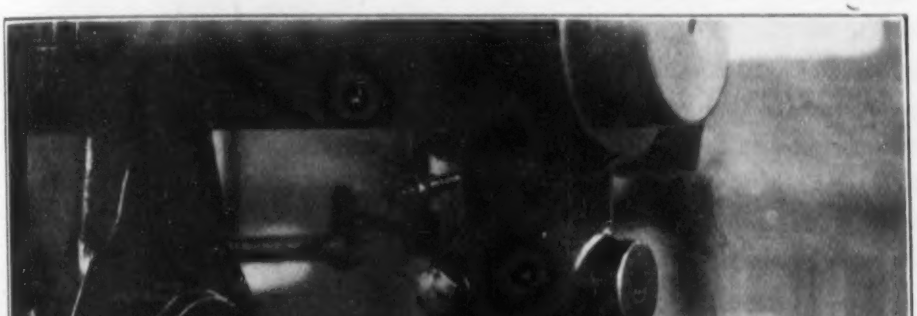


Fig. 17—Set of Sheet Tensile Test Specimens being Machined in Milling Machine with Special Cutter. Method of Clamping is Shown in the Photograph.

centage elongation of Armco ingot iron a series of tensile test specimens were prepared from a lot of 1-inch round bars which were as uniform in physical properties as possible. These test pieces had threaded ends and were machined to a diameter of 0.505 inch over the gage length. They conformed to the A. S. T. M. standard 0.505-inch round test piece in every respect except that the gage length varied from one to twelve inches. All the tests were made with the same testing machine and at the same speed (3/64th per minute throughout all tests). Five specimens were prepared for each gage length and the results are shown graphically in Fig. 14. All samples were marked off to inches and the elongation in each inch measured. An interesting result was obtained by taking the average elongation of those sections which were more than 1 inch distant from the fracture and from the ends of the specimen. This figure is based on the results on the 8, 10 and 12 inch samples and is 23 per cent. This is the theoretical elongation of a 0.505 inch round Armco ingot iron test piece of infinite length.

Tensile Tests on Sheets—For tensile tests on thin plate and sheet metal it is necessary to use special grips in the testing machine as the ordinary wedge grips are liable to cut the specimens near the edges, giving a tearing stress. It is also practically impossible to secure accurate alignment of thin sheet specimens in the ordinary wedge grips. The type of specimen used in these tests has already been discussed. Fig. 15 shows the special grips (30). These grips will adjust themselves to any slight inequalities in the specimen and will automatically align themselves on account of the spherical seats. Fig. 16 shows these grips in use in the testing machine.

The preparation of the sheet tensile test specimens requires special care as they are necessarily much smaller than those used for heavy plates and any lack of parallelism of the sides or nicks or other defects in the surface will exert a much greater influence on the results of the test. In preparing these test pieces the samples are usually sheared out of larger pieces with a foot-power shear or punched out with a special punch and die. The blank size is 5/8 inches wide and 9 inches long. A number of these strips are then clamped together between two heavy strips of the same size and held in a vise on the milling machine where

the parallel sides are machined. The heavy pieces protect the edges of the thin samples from becoming deformed in clamping.

On account of the extreme softness of Armco ingot iron it was found that an ordinary milling cutter did not give a good clean smooth cut but tended to tear the metal and necessitated a considerable amount of draw filing in order to get a good surface. After some experimenting a special cutter was obtained (31) which entirely overcame this difficulty. Fig. 17 shows a set of these samples being machined in the milling machine with this special cutter. The exact width of the parallel section is not as important as having it exactly parallel. The width should not vary more than 0.0005 inch from perfect parallelism.

In making a tensile test on these specimens it is advisable to use some sort of extensometer to determine the yield point as there is a chance of slippage in the jaws of the grips and this may cause a drop of the beam which does not correspond to the yield point. It is also desirable to operate the machine at a very slow speed.

In making tensile tests on sheet metal it is customary to determine only the yield point, tensile strength and per cent elongation. The accurate measurement of the fracture of sheet metal is difficult and for this reason the per cent reduction of area is not determined.

Effect of Various Variables on Tensile Properties—In studying the results of physical tests on any material it is well to consider what variables may affect these results. Of course the nature of the material itself, what it is, is of primary importance in influencing the results of physical tests, but when the same kind of material is under consideration, as in this case it is Armco ingot iron, there are other factors which must not be overlooked. The most important of these are, mechanical work, heat treatment, and finally, the conditions under which tested.

Mechanical work is generally understood to mean "cold work" of some kind such as rolling, drawing, etc., at room temperature. As a matter of fact any of these operations exert an influence on the properties of the finished product, whatever the temperature at which they are carried out. As an illustration, it may be mentioned that a complete investigation on this subject was carried out by Dr. A. Pomp (32) on low carbon steel. He made a series

of tests on this material, rolling it to get various amounts of reduction at a range of temperatures from atmospheric to 1650 degrees Fahr. (900 degrees Cent.). While such a complete investigation has not to our knowledge ever been made on Armco ingot iron, the effect of varying amounts of cold rolling on sheets has been studied (33).

For the purpose of this investigation a sheet of box-annealed

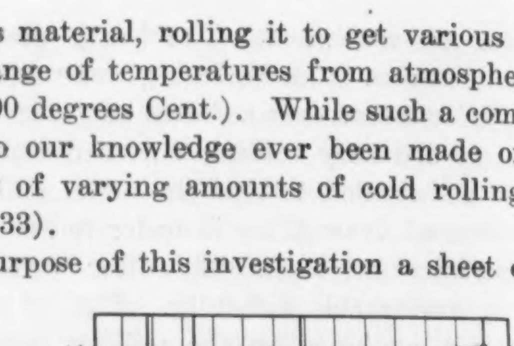


Fig. 18—Curves Showing the Effect of Cold Rolling on the Tensile Properties of Armco Ingot Iron Sheets.

16-gage (0.0625 inch) Armco ingot iron was chosen. The length of the sheet was carefully measured and a sample about 10 inches long, the full width of the sheet cut off. The length was again measured and the sheet given ten successive passes on the "cold rolls." After the first, second, fifth and tenth passes, the length of the sheet was measured and a sample cut as before. The elongation of the sheet (reduction of thickness) was computed from the linear measurements. Tensile tests and Rockwell hardness tests were made on the material after these varying amounts of cold working. The results of these tests are plotted graphically in Fig. 18.

From this it will be seen that mechanical work has a very important influence on the physical properties. The yield point is more than doubled and the percentage elongation is more than cut in half by even some 6 or 7 per cent reduction in cold rolling. The hardness is similarly affected.

The effect of heat treatment on physical properties is quite as important as mechanical work or cold working. This is a subject of itself and can be dealt with only briefly in this paper. Heat treatment of most ferrous metals is based on a knowledge of the behavior of the metal as its temperature is varied over a range from room temperature to the melting point. Within this range certain "transformations" or internal rearrangements take place. These changes are not instantaneous and by rapid cooling from temperatures above one of these "critical" points it is generally possible to retain some of the material in the same form as it was at the elevated temperature.

With low carbon materials and especially with Armco ingot iron there is another factor that is involved in the heat treatment and that is called "re-crystallization on annealing after cold working." When such materials are cold-worked (which means here any temperature below the A_3 point) a certain amount of strain is set up. When this strained metal is heated, the strain is relieved and at the same time a recrystallization of the deformed grains takes place. A number of factors influence this phenomenon. These are (1) amount of cold work, (2) size of grains, (3) temperature at which the cold work was done, (4) annealing temperature, (5) time of annealing, and (6) rate of cooling from annealing temperature. All of these variables influence the physical properties of the finished material. It can therefore be readily seen that the heat treatment of low carbon material which receives an appreciable amount of cold working is in reality quite a complicated problem. In the rolling of sheets a large part of the working is below the A_3 point (all except the rolling of the ingots into sheet bars). It will therefore be impossible to give here any detailed data on the effect of these variables on the physical properties of the finished product. A number of investigators have studied the effects of these variables and the reader is referred to their work (34) (35).

In general it may be said that the more severe the cold rolling and the lower the temperature at which it is performed, the lower

is the recrystallization temperature. The other variables mentioned above also exert an effect and certain other generalizations regarding them will be found in the sources referred to.

The temperature at which physical tests are made has a pronounced effect upon the results because the physical properties of materials change with temperature. It is much more difficult to conduct such tests at other than room temperature and consequently it is only in comparatively recent years that much work has been done along this line. The effect of temperature on the results of the tensile test has received more attention than any other physical property, partly because these tests are easier to conduct at elevated temperatures than some of the others and partly because the tensile properties are so fundamental.

The effect of temperature on tensile strength will be spoken of later but in general it may be said that the tensile strength and yield point decrease with increasing temperature. For ferrous materials, especially pure iron and the straight carbon steels, there is a notable exception to this rule. These materials exhibit their maximum strength at about 600 degrees Fahr., this strength being even higher than at room temperature.

Plates—As a standard specification for physical properties of hot-rolled Armco ingot iron plates, the manufacturers give the following which in effect is a form of minimum requirement which they guarantee this material to meet.

1. Physical Properties and Tests

The plates shall conform to the following requirements as to physical properties:

(a) Tensile strength not less than 38,000 pounds per square inch.

(b) Yield point not less than one half the tensile strength.

(c) Per cent elongation in 8-inch not less than 22 per cent (see modification).

2. Modification in Elongation

For plates under 7/16-inch in thickness a deduction of 1 from the percentage of elongation specified in section 1 shall be made for each decrease of 1/16 inch in thickness below 7/16 inch.

3. Bend Tests

(a) Cold Bend Tests. The test specimens shall bend cold through 180 degrees without fracture on the outside of the bend portion.

For material under 7/16 inch flat on itself.

On material thicker than 7/16 inch around a pin, the diameter of which is equal to the thickness of the specimen.

4. Test Specimens

Tension and bend specimens shall be taken from the finished plates and shall be of the full thickness of the plate as rolled. The

longitudinal axis of the specimen shall be parallel to the direction in which the plates are rolled.

There shall be no tests made on material lighter than 10 gage upon which the above specification shall apply.

Other points such as finish, retests, inspection, etc., are covered in the standard specifications, but the above extracts give all the requirements as far as physical properties are concerned.

Hot-Rolled Plates—The tensile properties of hot-rolled Armco ingot iron plates of various thickness are given in Table IV. These values (75) are all for longitudinal tests and are averages of several tests. As the finishing temperature varies somewhat in the manufacture of hot-rolled plates, so the tensile properties will vary from the results given. These values may be taken as representative of this grade of material.

Table IV
Tensile Properties of Hot-Rolled Armco Ingot Iron Plates

Nominal Thickness Inches	Yield Point #/in²	Tensile Strength #/in²	% Elong in 8″	Per Cent Reduction of Area
1/8	26,500	43,150	23.6	Not measured
3/16	40,000	47,350	22.0	64.7
1/4	43,330	48,500	24.0	74.2
5/16	34,200	43,800	22.9	68.5
3/8	37,300	45,650	28.2	77.7
7/16	27,350	44,700	27.0	67.2
1/2	29,650	45,200	27.9	73.9

It will be seen that all of these tests more than meet the tensile requirements guaranteed in the "Standard Specifications."

Hot-Rolled Bars—The results of tensile and hardness tests (36) on hot-rolled Armco ingot iron bars of various sizes is given in Table V. These bars were all purchased in the open market and tested "as received."

Table V
Tensile and Hardness Tests on Armco Ingot Iron Hot-Rolled Rods

Nominal Size	Yield Point #/in²	Tensile Strength #/in²	% Elong in 8″	% Reduction of Area	Rockwell Hardness
3/8″ Round	37,080	44,660	24.75	73.6	B-54.5
1/2″ Round	31,440	44,040	32.78	70.4	B-46
5/8″ Round	27,080	44,080	34.2	76.23	B-45
3/4″ Round	28,130	41,900	37.3	75.7	B-46
7/8″ Round	25,730	42,250	38.6	74.43	B-39

These results are the average values obtained from nine tests of each size. It will be seen that there is a progressive increase in ductility from the smaller to the larger sizes. This is shown by the variation in yield point, percentage elongation and Rockwell hardness. It is probably the result of lower finishing temperatures in rolling the smaller sizes.

Cold-Rolled Bars—The effect of cold rolling on the physical properties of sheets has already been discussed and it was shown that the yield point, tensile strength, and hardness are all increased by this cold working. As the reductions in cold rolling or drawing wires and rods are usually greater than those given sheets, there is consequently a greater difference between the physical properties of annealed and cold drawn rods. The data (37) given in Table VI, on cold-rolled Armco ingot iron rods is presented here for comparison with the properties of hot-rolled rods just discussed.

These results are for tests on three different 5/8 inch rods of cold-rolled Armco ingot iron purchased in the open market and tested "as received" without any machining. The elongation was measured on an 8-inch gage length.

Table VI
Tensile and Hardness Tests on Armco Ingot Iron Cold-Rolled Rods

Rod No.	Yield Point #/in²	Tensile Strength #/in²	% Elong. in 8"	% Reduction of area	Hardness Rockwell	Brinell
1	57,400	60,300	10.88	70.8	B-78	126
2	59,300	62,600	7.50	65.7	B-80	140
3	58,700	63,000	9.38	68.2	B-81	146

Wire—The physical properties of wire can be varied over quite a range by varying the amount of cold drawing and the intermediate annealings. Thus we have "soft annealed wire" and "hard drawn wire" as two extremes in this respect. It has been found by experience that various "tempers" or degrees of hard drawing are required according to different uses for which the wire is intended. If the wire will have to withstand much bending in being fabricated into some finished product it should not be too hard and stiff. On the other hand, it may be desirable and even necessary that it be as strong and stiff as possible. The requirements depend on each individual case. It should be stated

that the additional "hardness" produced by cold working the wire is only stable at ordinary temperatures. When heated to even less than a dull red heat some of the extra stiffness is lost and this loss is increased as the temperature is raised.

The tensile strength of Armco ingot iron wire can be varied over a wide range by the means above described. In the dead soft condition it will test as low as 38,000 pounds per square inch, while it can be cold drawn until it is over 100,000 pounds per square inch, (with a loss of ductility of course).

One of the large uses for Armco ingot iron wire is for welding rods and electrodes. It is used on a large scale for both oxyacetylene and electric arc welding. This is another example of the difference in physical properties imposed by different working conditions because oxyacetylene welding requires a fairly soft wire while electric arc welding calls for a hard drawn wire.

Sheets—The tensile properties of Armco ingot iron sheets vary according to the methods used in processing and this in turn

Table VII
Tensile Properties of Various Grades of Armco Ingot Iron Sheets

Grade	Yield Point $\#/in^2$	Tensile Strength $\#/in^2$	% Elong in 2"	% Elong in 8"	% Reduction Area	Rockwell Hardness
ARMCO Ingot Iron "Black"	34,100	42,900	18.5			B-36
ARMCO Ingot Iron "Blue Annealed"	25,800	40,100		30.3	77.2	B-53
ARMCO Ingot Iron "Galvanized"	27,200	39,800	29.2			B-51
ARMCO Ingot Iron "Enameling stock for flat work	28,500	38,500	23.5			B-32
ARMCO Ingot Iron Enameling Stock	27,300	47,000	29.0			B-40

depends upon the purpose for which the sheets are intended. Sheets that are used for flat work such as enameled signs and backing for bill boards (made of galvanized sheets and known as poster board stock) do not need to have exceptional ductility such as is necessary for drawing stock. In fact, the stiffer such material is, the better it serves the purpose. It will thus be seen that wide variation in physical properties is necessary according to use.

Table VII gives the average physical properties determined on a number of samples (38) taken from different grades of sheets.

It will be noted that the reduction of area is given only for the "blue annealed" grade. This determination cannot be made on light gage sheets such as represented in the other grades. This point has been already discussed under another subject. The sheets of "blue annealed" material were mostly all heavy gage and thus the reduction of area could be determined on them.

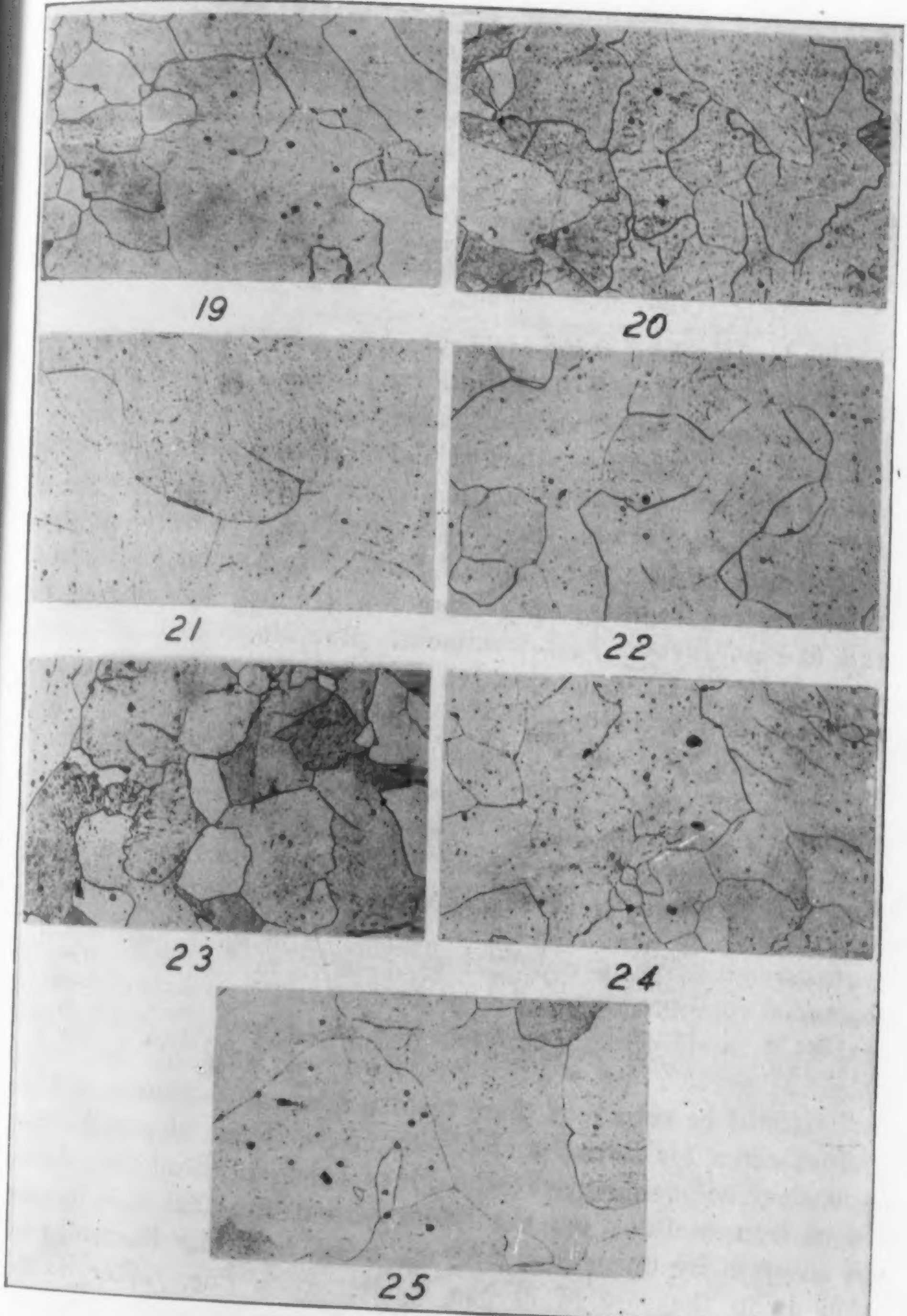
Table VIII
Effect of Forging Practice and Heat Treatment on Tensile Properties of Armco Ingot Iron

Bar No.	Treatment	Y. P. #/in²	T. S. #/in²	% Elong. in 2"	% Red. Area
1	As forged, finished cold	26,900	43,800	41.8	75.6
2	As forged, finished hot	19,100	42,200	44.7	77.3
3	Finished hot, annealed 25 hrs. at 1650° F. slow cool	18,300	41,000	47.0	70.6
4	Finished hot, air cooled from 1725° F.	19,300	43,500	45.0	73.7
5	Finished hot, water quench from 1725° F.	30,300	47,000	36.2	70.0
6	Finished hot, water quench from 1725° F. draw at 1200°	20,800	42,700	41.8	71.1
7	Finished hot, annealed 2½ hrs. at 1650° F., fairly slow cooled (faster than No. 3)	18,900	42,900	43.2	72.8

Forgings—In order to determine the effect of variations in forging practice and subsequent heat treatment of Armco ingot iron, a series of tests (39) was conducted according to the following outline:

Seven small bars 1¼ x 4 x 10 inches were forged from the same billet. The treatment of these pieces was as follows:

Bar 1—Forged below 1600 degrees Fahr. and finished cold. Tested in this condition without any subsequent heat treatment.
Bar 2—Forged at about 2000 degrees Fahr. and finished above 1700 degrees Fahr. Tested in this condition without any subsequent heat treatment.
Bar 3—Forged at about 2000 degrees Fahr. and finished above 1700 degrees Fahr. Annealed 25 hours at 1650 degrees Fahr. and cooled very slowly.
Bar 4—Forged at about 2000 degrees Fahr. and finished above 1700 degrees Fahr. Normalized by heating to 1725 degrees Fahr., holding 4 hours and air cooling.



Photomicrographs of samples of Armco Ingot Iron Used to Determine the Effect of Variations in Forging Practice and Subsequent Heat Treatment. Fig. 19—Bar 1, Fig. 20—Bar 2, Fig. 21—Bar 3, Fig. 22—Bar 4, Fig. 23—Bar 5, Fig. 24—Bar 6, Fig. 25—Bar 7. The various treatments given these bars are described in the text of this article. Note: all photomicrographs etched with 3 per cent nital. Magnification 100x.

Bar 5—Forged at about 2000 degrees Fahr. and finished above 1700 degrees Fahr. Heated to 1725 degrees Fahr. for 4 hours and water quenched.

Bar 6—Forged at about 2000 degrees Fahr. and finished above 1700 degrees Fahr. Heated to 1725 degrees Fahr. for 4 hours and water quenched. Reheated to 1200 degrees Fahr. for 30 minutes and air cooled.

Bar 7—Forged at about 2000 degrees Fahr. and finished above 1700 degrees Fahr. Annealed in small annealing box in laboratory muffle furnace. Held for 2½ hours at 1650 degrees Fahr., furnace cooled at 1390 degrees Fahr. in 1½ hours. Box withdrawn from furnace and cooled in air.

Three standard 0.505-inch round tensile test specimens were cut from each of these forged blocks. Table VIII gives the average values obtained from the tensile tests.

Bar No. 1 which was forged and finished cold has the highest yield point and tensile strength of any of the bars with the exception of No. 5 which was water quenched. However, it shows next to the highest reduction of area. The highest reduction of area occurred in the case of Bar No. 2 which was finished hot and had no further heat treatment. Bar No. 5 had the highest yield point and tensile strength and lowest per cent elongation and reduction of area.

The effect of water quenching on the physical properties of Armco ingot iron has been reported elsewhere (40) (41). In connection with tests on the fatigue of metals, Prof. H. F. Moore reports the following tensile and hardness values for Armco ingot iron "as received," and quenched from 1500 degrees Fahr.

Condition	Propor. Limit #/in²	Yield Point #/in²	Tensile Strength #/in²	% Elong. in 2"	% Red. of Area	Brinell Hardness
As Rec'd	16,100	19,000	42,400	48.3	76.2	69
Quenched	35,000	36,300	50,000	36.3	76.0	109

It will be seen that these results check quite closely with the values given for Bars 2 and 5 which were tested unquenched and quenched respectively. It should be borne in mind that Armco ingot iron contains practically no carbon and that this increase in strength by quenching does not come from any hardening action as in the case of carbon steels. It is due, rather, to the effect of the heat treatment on the grain size.

Microscopic examination of the heat treated samples shows quite a variation in the size of the grains. The micrographs in Figs. 19 to 25 show typical structure of these samples. It will be

seen that the long time annealing and slow cooling of sample No. 3 has produced a very coarse grain which in turn results in extremely soft material. (This bar had a Brinell hardness of only 82.) On the other hand, the water quenched bar No. 5 has the smallest grain size of any of the samples. It therefore appears that the variation in physical properties obtained on these Armco ingot iron forgings is largely a function of the grain size.

Effect of Temperature on Physical Properties of Armco Ingot

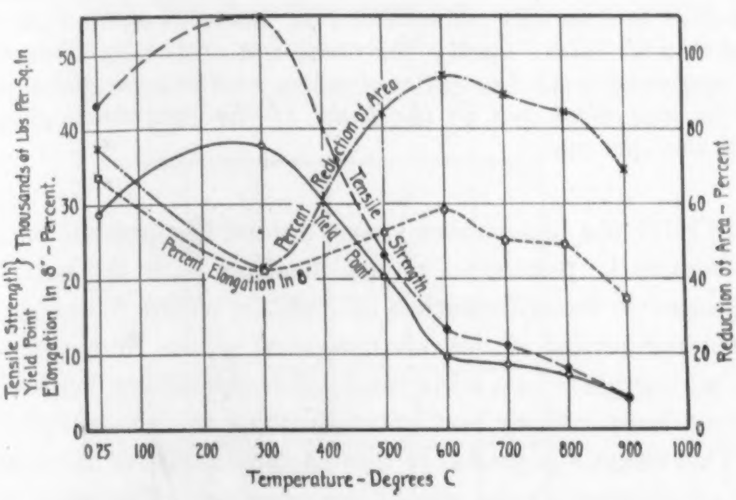


Fig. 26—Curves Showing the Physical Properties of Armco Ingot Iron at Elevated Temperatures.

Iron—On account of the large number of variables involved, the methods of conducting physical tests at elevated temperatures are not so well standardized as for tests at room temperature. Nevertheless, a large amount of work has been done by numerous investigators on the physical properties of materials at high temperatures. In 1924 the American Society for Testing Materials held a symposium on this subject and the papers presented furnish a splendid survey of all the work done up to that time (42).

In order to determine the tensile properties of Armco ingot iron at elevated temperatures, a series of tests (43) was conducted on 3/8-inch hot-rolled plates. The results of these tests are plotted graphically in Fig. 26.

The irregularity in the curves at 570 degrees Fahr. (300 degrees Cent.) is normal for most ferrous metals—especially those of low carbon content and corresponds to the "blue-brittle" range.

(To be Continued in March TRANSACTIONS)

ON THE DETERMINATION OF THE HETEROGENEOUS FIELD IN THE IRON-NICKEL SYSTEM

By Kotaro Honda and Sansaku Miura

Abstract

By means of the dilatometric analysis, the heterogeneous field in iron-nickel alloys was determined. By the application of the law of depression of freezing point, the lowering of the A_3 point of iron by the addition of nickel to iron was calculated and found to agree with the observed data. Lastly the variation of the coefficient of expansion with the concentration in the iron-nickel system was discussed in the light of the structural change of the system.

WITHIN the last twelve years, one of the present writers[1] has frequently published papers dealing with the nature of the A_2 or magnetic transformation in iron, in which it was shown that this transformation is not a change of phase, but a progressive change taking place in a wide range of temperature, beginning from the lowest temperature and extending up to the critical temperature. This change is probably due to the change of internal atomic energy accompanying the rise of temperature. The above view was afterwards confirmed by the X-ray analysis, and is now accepted by most of the scientists in the world. Since the A_2 transformation is not a change of phase, this point or the line which shows its change with an addition of a foreign element into iron, should be excluded from the equilibrium diagram of the iron-carbon system, which represents the change of phase at high temperatures, or it should be represented by a different kind of line, such as, a dotted line, as is already done in the publications of our institute.

In the case of iron-nickel alloys, we find also a transformation of the same nature as the A_2 change in iron, both on the iron and nickel sides. These transformation points or lines should there-

[1]Science Reports of the Tohoku Imperial University, Sendai, Japan, Vol. 4, 1915, P. 169; Vol. 6, 1917, P. 213; Vol. 11, 1922, P. 119; Vol. 13, 1925, P. 264; Vol. 15, 1926, P. 247.

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. Of the authors, Dr. Kotaro Honda is honorary member of the Society and professor of metallurgy, Tohoku Imperial University, Sendai, Japan. Sansaku Miura is associated with Dr. Honda at the Imperial University. Manuscript received May 7, 1927.

fore be omitted in the equilibrium diagram of the iron-nickel system, and thus the diagram in the solid phase of the system is much simplified, leaving only two lines representing the beginning and the end of the A_3 or alpha to gamma transformation, as shown in Fig. 1. That this diagram agrees satisfactorily with the result of the X-ray analysis, was shown by A. Osawa[2] in our institute. Dr. T. Kasé[3] also thoroughly studied the same system of alloys from the metallurgical point of view and confirmed the above conclusion. According to him, the A_3b line does not stop at a point a little above room temperature, as it is usually believed to do, but actually extends far below room temperature. He also explained the hetero-

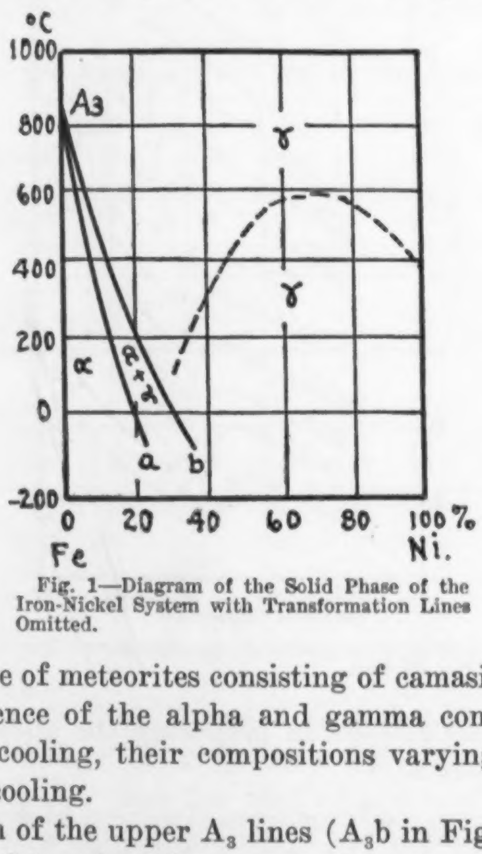


Fig. 1—Diagram of the Solid Phase of the Iron-Nickel System with Transformation Lines Omitted.

geneous structure of meteorites consisting of camasite and taenite as due to the presence of the alpha and gamma components formed during a rapid cooling, their compositions varying naturally with the rapidity of cooling.

The position of the upper A_3 lines (A_3b in Fig. 1) has hitherto been repeatedly determined by means of the thermal and magnetic analysis, and is now well known; but that of the lower A_3 line (A_3a in Fig. 1) has not yet been determined. The present investigation is to give accurate data for the temperature range of

[2]Science Reports of the Tohoku Imperial University, Sendai, Japan, Vol. 15, 1926, P. 385.

[3]Science Reports of the Tohoku Imperial University, Sendai, Japan, Vol. 14, 1925, P. 173; Vol. 14, 1925, P. 537.

the A_3 transformation in the pure iron-nickel system by means of the dilatometer constantly used in our institute, that is, to determine the beginning and ending points of the transformation during heating and cooling. For the measurement of expansion below room temperature down to that of liquid air, the same apparatus as described by Dr. T. Kasé[3a] was used.

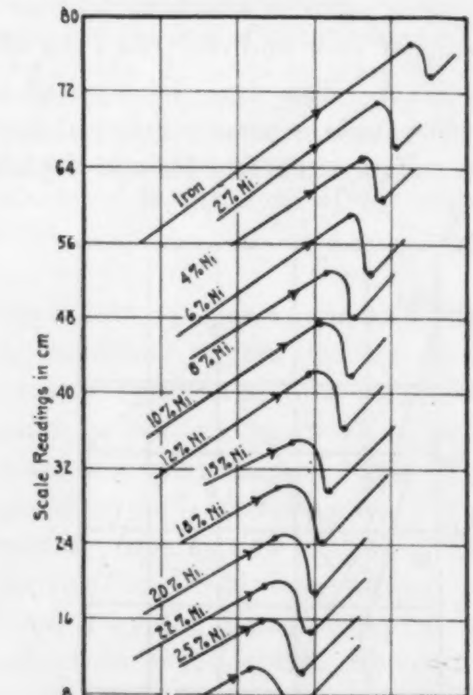


Fig. 2—Dilatation-Temperature Curves During Heating.

The raw material used in preparing the alloys contained the following constituents:

Constituents	Fe	Co	C	P	Per Cent S	Si	Al	Mn	Cu
Armco iron	..	..	0.03	0.008	0.023	0.01	trace	0.02	0.03
Mond nickel ..	0.10	trace	0.37	trace	trace	0.006	trace	trace	0.013

The alloys were made by melting together Armco iron and

[3a]See footnote 3.

Mond nickel in a Tammann furnace in alundum crucibles; they were cast in an iron mold into a bar, 6 millimeters thick and 20 centimeters long, then annealed at 1650 degrees Fahr. (900 degrees Cent.) for 1 hour and slowly cooled. Afterwards, they were turned on a lathe to a round bar, 5 millimeters thick and 15 centimeters long. These specimens were then placed in the dilatometer and the change of their lengths was observed during slow heating and cooling. The rate of heating or cooling was usually 2 degrees Cent. per minute, and the measurement was in all cases made in vacuo.

The results of observation are given in curves in Figs. 2 and 3, and the temperatures of the beginning and ending of the A_3 transformation estimated from these curves are given in Table I and in Figs. 4a and 4b.

Table I

Temperatures at the Beginning and End of the A_3 Transformation

Ac_3 point

Alloys (% Ni)	0 (Iron)	2	4	6	8	10	12	15	18
Beginning Pt. ..	860°	786°	724°	690°	631°	611°	592°	538°	508°
Finishing Pt. ...	905°	820°	784°	751°	709°	704°	580°	642°	622°

Alloys (% Ni)	20	22	25	28
Beginning Pt. ..	490°	469°	460°	440°
Finishing Pt. ...	602°	587°	567°	557°

Ar_3 point

Alloys (% Ni)	0 (Iron)	2	4	6	8	10	12	15
Beginning Pt. ..	889°	777°	706°	636°	556°	515°	452°	338°
Finishing Pt. ...	850°	728°	626°	533°	397°	338°	248°	110°

Alloys (% Ni)	18	20	22	25	28	30	31	32	33
Beginning Pt. ..	233°	193°	155°	78°	7°	–9°	–38°	–50°	–78°
Finishing Pt. ...	21°	–31°	–100°						

The ordinates in Figs. 2 and 3 represent the dilatation, and the abscissa the corresponding temperatures; the curves in Figs. 2 and 3 are respectively, those for heating and cooling. In the case of the heating curves, the estimation of the beginning and finishing temperatures of the transformation can be exactly made; two points marked by (·) on each curve show the estimated temperatures. In the case of the cooling curves, the beginning temperature of the transformation can also be estimated exactly; but it is somewhat difficult to determine the finishing point of the transformation, as the last stage of the transformation is very gradual. Hence as

shown in Fig. 3, the straight portions of the heating curves are drawn in dotted lines a little displaced above each corresponding curve, and the temperature at which after the abnormal expansion, the cooling curve becomes parallel to that of the heating curve, is taken as the terminating point (see Fig. 3) of the transformation. In the actual case of low nickel alloys, the straight portions of the

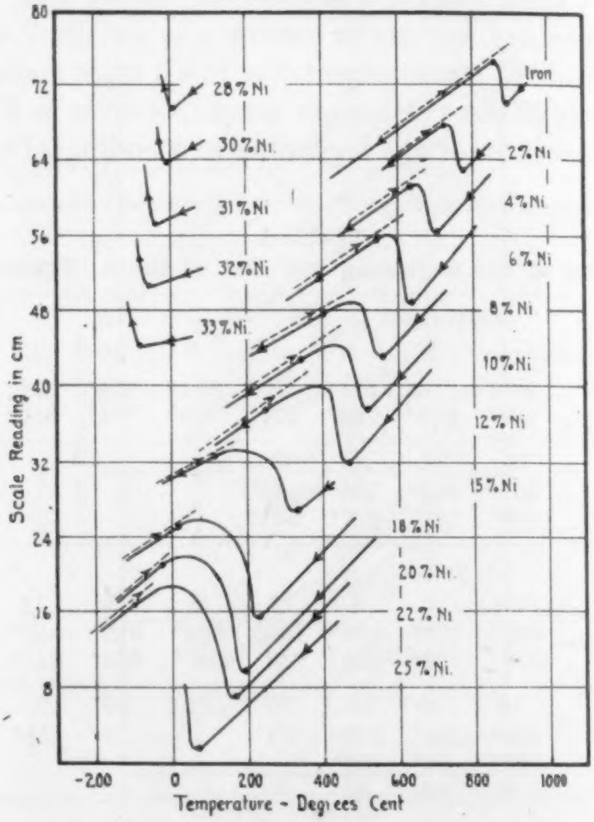


Fig. 3—Dilatation-Temperature Curves During Cooling.

heating and cooling curves for the same specimen coincided with each other, but in the case of high nickel alloys, the cooling branch fell a little below the heating one. The curves in Fig. 4a and 4b show the beginning and finishing temperatures of the A_3 transformation with respect to the concentration of nickel.

From Figs. 2 and 3, we see that the transformation range or temperature interval is very small in pure iron, but that with an increasing content of nickel in iron, it becomes gradually greater. Fig. 4 shows that during cooling the A_3 point falls rapidly with an increasing content of nickel, and at a higher concentration falls

somewhat slowly. The commencing line of the A_3 transformation cuts the concentration axis of nickel at 29 per cent, and the finishing line of transformation the same axis at 18.7 per cent. During heating, the fall of the A_3 point of iron is at first equally rapid as in the case of cooling, but afterwards it becomes less and less, as

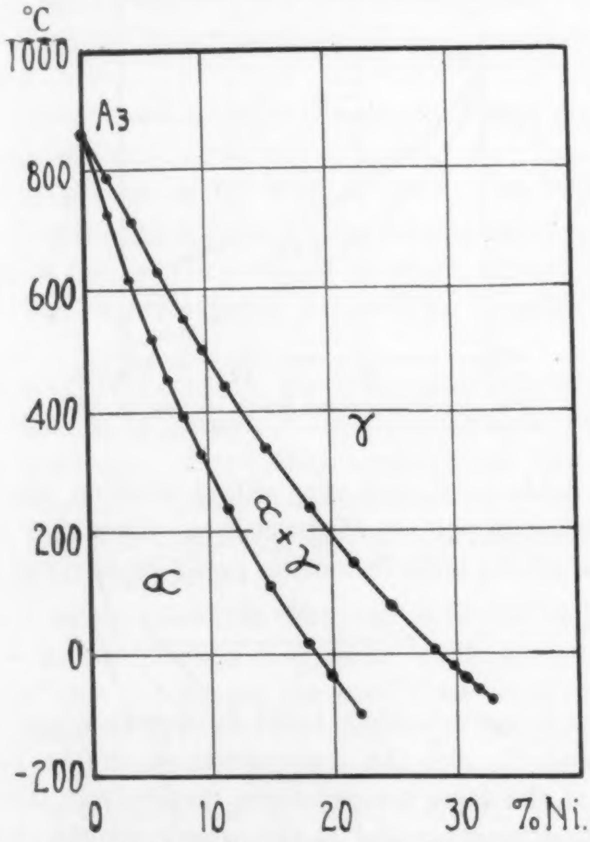


Fig. 4a—Showing the Effect of Cooling on the A_3 Point.

the content of nickel further increases. Consequently the A_3 lines during heating are markedly convex toward the concentration axis. It is a well known fact that in the case of pure iron, the range of the A_3 transformation becomes less as the rate of heating or cooling decreases, and almost vanishes, if this rate is made sufficiently small. This is, however, not the case, when iron contains a quantity of nickel. In the present case, the rate of heating or cooling was the same for different alloys, and not sufficiently small for the transformation of pure iron to take place at a definite temperature. Hence as the ideal case, the A_3 lines in Figs. 4a and 4b were drawn so as to start from a point in the iron axis.

Thusfar the heterogeneous field in the equilibrium diagram in the iron-nickel system being determined, it is interesting to see whether the law of depression of the freezing point[4] is also applicable to the present case, that is, to the fall of the A_3 point. As

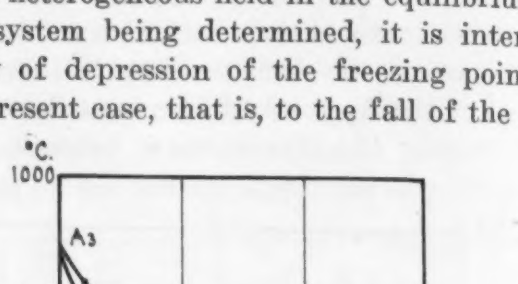


Fig. 4b—Showing the Effect of Heating on the A_3 Point.

this law only holds good in a very dilute solution, the test should be made in the initial portion of the curves, where they are straight. The depression of the transformation point δT is given by

$$\delta T = -\frac{RT^2 (C_l - C_s)}{\lambda m}$$

where T is the transformation point in question and R the gas-constant, C_L and C_s are the concentrations in the liquidus and solidus points at the same temperature, respectively, λ is the latent heat of the transformation and M the atomic weight of iron.

In the case of cooling, we may take C_l and C_s at 1112 degrees Fahr. (600 degrees Cent.), then

$$R = 1.985, \qquad C_l - C_s = 2.95\%,$$
$$T = 870 + 273 = 1143° \qquad \lambda = 5.35\ (^4),\ m = 55.8,$$
$$\text{whence } \delta T = 255°.$$

The actually observed value is 518 degrees Fahr. (270 degrees Cent.).

In the case of heating, we may take C_l and C_s at 1508 degrees Fahr. (820 degrees Cent.), then

$$T = 887 + 273 = 2120 \text{ degrees Fahr. (1160 degrees Cent.)}$$
$$\delta T = 161 \text{ degrees Fahr. (72 degrees Cent.)}$$
$$C_l - C_s = 0.8 \text{ per cent}$$

[4]Science Reports of the Tohoku Imperial University, Sendai, Japan, Vol. 14, 1925, P. 219.

The observed value is 152 degrees Fahr. (67 degrees Cent.). If we consider the uncertainty of determining C_1-C_8, the above agreement between the theoretical and observed values is to be considered as satisfactory.

From Fig. 4 and also the above calculation, it is evident that the initial portions of the Ac_3 and Ar_3 curves almost coincide with each other, though the latter portions of the one gradually diverge from the other.

In taking these curves, the heating and cooling were conducted very slowly, but the two curves are so much apart from each other; hence two sets of curves in Fig. 4 show both the incomplete equilibrium diagram, and the true equilibrium diagram must consist of two lines, the initial portions of which almost coincide with the observed, but the remaining portions lie between those of the observed curves.

Lastly it may not be out of place to make some remarks on the coefficient of thermal expansion of the iron-nickel alloys. The mean coefficient of expansion at ordinary temperature has already been made by Guillaume, Kaye, Leman-Blosetke, Werver[5], Honda-Okubo[6], etc. Fig. 5 is a reproduction of the result obtained by the last mentioned investigators.

It is a well-established fact that martensite has a less coefficient of expansion and austenite a greater coefficient, than pearlite. Hence as seen from the figure, the coefficient of expansion of iron decreases as nickel is added to it, since with an increasing content of nickel the structure of the alloys becomes more martensitic. But with from 18 to 25 per cent of nickel content, the austenite content gradually increases and consequently the coefficient of expansion increases. On the other hand, the coefficient of expansion of nickel gradually decreases at first by the addition of iron to nickel, and then rapidly, till the composition of the alloy reaches that of invar, that is, 36.1 per cent of nickel.

As to the cause of the small expansibility of invar, nine years ago one of the present writers[7] made a remark that it is intimately connected with the A_3 transformation of the alloy, which is lowered to the vicinity of room temperature; but the present investigation

[5] See Landolt-Bernstein's table.

[6] Science Reports of the Tohoku Imperial University, Sendai, Japan, Vol. 13, 1924, P. 101.

[7] Science Reports of the Tohoku Imperial University, Sendai, Japan, Vol. 6, 1918, P. 321,

and also that made by Dr. T. Kasé show that at the concentration of invar, the A_3 transformation has already been lowered to below -148 degrees Fahr. (-100 degrees Cent.) and hence does not take place in the vicinity of room temperature.

The curves in Fig. 6 are the results obtained by Dr. T. Kasé with a dilatometer. The ordinates represent the dilatation in

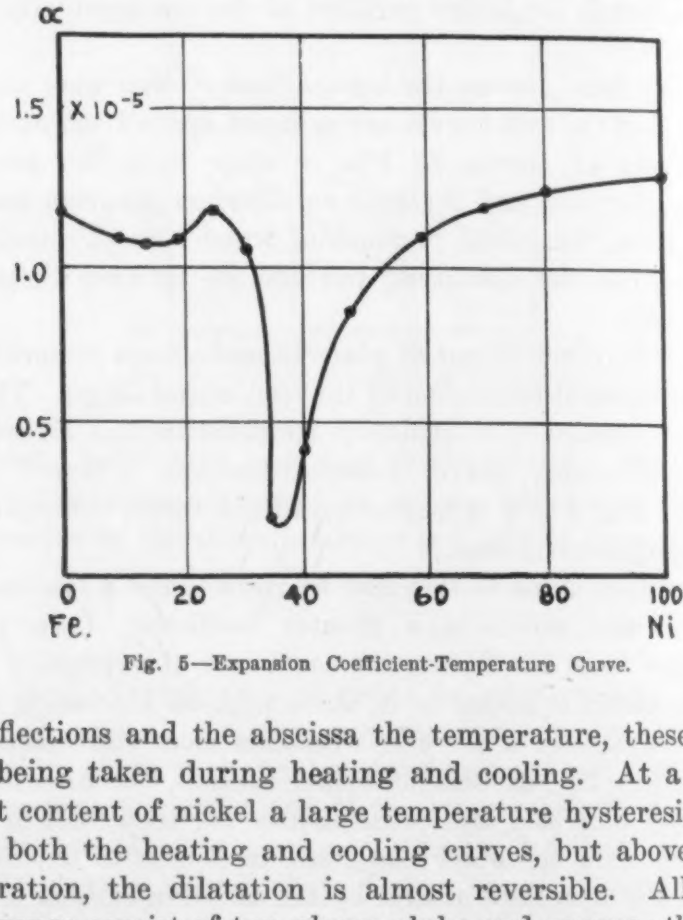


Fig. 5—Expansion Coefficient-Temperature Curve.

scale-deflections and the abscissa the temperature, these dilatation curves being taken during heating and cooling. At a 25 to 33.4 per cent content of nickel a large temperature hysteresis is observable in both the heating and cooling curves, but above the latter concentration, the dilatation is almost reversible. Alloys of the former range consist of two phases alpha and gamma; the magnetic or A_2 transformation of the gamma phase is almost reversible for heating and cooling, while the A_3 transformation of the other phase shows a considerable irreversibility.

From the curves in Fig. 6, it is noted that during cooling the Ar_3 point falls continuously in the case of an increasing content of nickel from 25 to 33.4 per cent, and that at above 35.5 per cent of nickel content, the same point is no longer observable down to the temperature of liquid air. In the case of invar, the range of temperature, in which the coefficient of expansion is very small, lies

in the ferromagnetic region in the gamma phase, and hence this abnormal property can have no connection with the A_3 transforma-

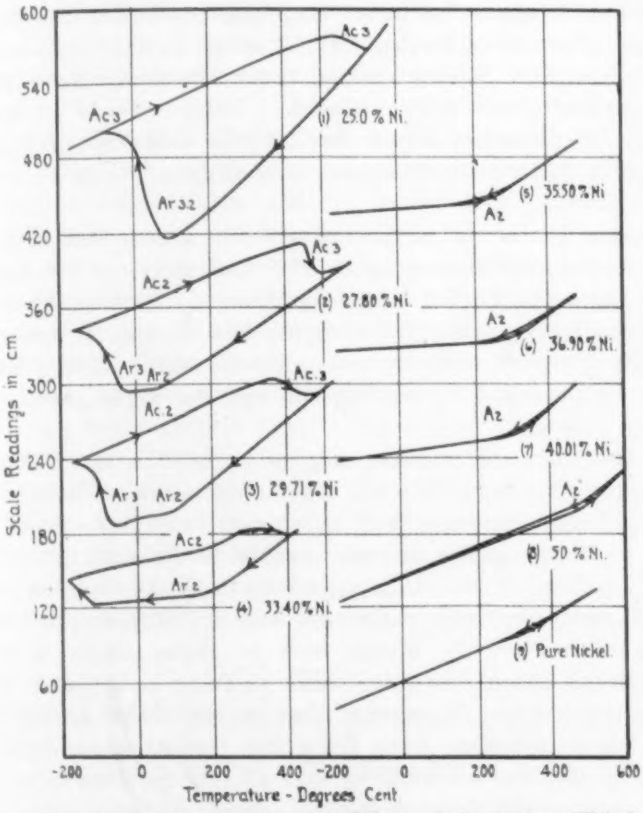


Fig. 6—Curves Showing the Effect of Increasing Nickel Content on the Ar_3 Point When Exposed to Temperatures Down to That of Liquid Air.

tion. In fact this is a property characteristic of the ferromagnetic alloy in the gamma phase.

DISCUSSION

Written Discussion: By Paul D. Merica, Director of Research, International Nickel Co., New York City.

The discussion of this subject by Professor Honda and Mr. Miura is very interesting and in its principal conclusion follows the suggestion of T. Kasé (referred to by the authors); viz., that the so-called "reversible" transformation of iron-nickel alloys is not a phase transformation at all, but represents an intra-atomic change similar to that occurring in iron at A_2. This view represents a departure from the classical one sponsored by Guertler and others.

The writer is particularly interested in this conclusion since some years ago he had independently made the same argument in an unpublished lecture (1925). At that time the evidence was less abundant in

favor of this conception than it is today, but seemed even then adequate. Today with our knowledge of X-ray structure evidence we should have to accept a very curious situation were we to adhere to the older theory; namely, that two space lattices; viz., the reversible alloys above and below the transformation, having (1) identical atoms, (2) identical lattice constant, (3) identical lattice system, could not merge in solid solution,—i. e., were separate, immiscible phases. This, in view of the fact that quite commonly, different atoms having the same space lattice system, but of different lattice constant, are generally miscible in solid solution in all proportions.

So it seems better to adopt the simpler assumption and agree that the reversible transformation is chiefly and only an electronic change of some sort, associated with magnetic change. And as Professor Honda points out there is no necessity for urging the apparent eutectoid structure of meteors as evidence for the older theory, since such a structure can quite readily be produced by cooling through the alpha-gamma heterogeneous field.

One of the arguments made originally by Professor Honda, among others, in support of the view that the A_2 transformation in iron was not a phase transformation was that it was strictly reversible, and hence quite unlike ordinary phase transformations which are likely to lag on heating and cooling. And this argument may be applied with almost equal force to the reversible iron-nickel alloys. But curiously enough the magnetic transformation in nickel and in these alloys is not strictly reversible although the lag is quite small and not comparable with that of the "irreversible" one. It appears that in the nickel transformation we have one which is different both from the typical phase type and from a typically magnetic one as well,—a sort of intermediate type! It would appear to be well worth further study.

The "irreversible" transformation of the alloys containing up to about 30 per cent of nickel would also merit further study since there are some most peculiar things about it. The principal object of such study would be to establish its exact location,—i. e., in equilibrium. I note that Professor Honda apparently chooses the equilibrium position of the alpha-gamma heterogeneous region (in Fig. 1) as coinciding with the beginning and end of the transformation on cooling. I must confess to some doubt as to this coincidence, but possibly the author has reasons for so doing which he has not discussed.

There is little question that the nickel-iron equilibrium is one of the most puzzling and most interesting ones known—or perhaps I had better say, unknown. With the exception of the solidus-liquidus transition the behavior of this series of alloys up to 900 degrees Cent. is hardly in any respect "orthodox". A more intimate knowledge of this series alone would constitute a substantial contribution to the subject of theoretical metallurgy.

It is most fortunate that Professor Honda and his associates have found opportunity to devote some attention to it and it is to be hoped that they may continue their very constructive investigations.

Authors' Reply

The authors heartily thank Dr. P. D. Merica for his discussion of their paper and are very glad to find that he agrees with the equilibrium diagram of iron-nickel alloys investigated in their institute. The authors would like to make some remarks about the questions he has raised:

(1) According to our magnetic determinations often made in our institute, nickel and its "reversible alloys" are reversible just in the same degree as in the case of pure iron, and hence we conclude that nickel transformation is exactly the typical magnetic one and can be no other.

(2) The determination of the boundary lines between alpha and gamma solid solutions in the state of perfect equilibrium can only be done with the infinitely slow rate of heating or cooling; that is to say, it cannot be actually possible. A practically possible slow heating or cooling gives always a pseudo-equilibrium diagram, as shown in Figs. 4a and 4b. Thus our diagrams for heating and cooling give us necessary information about the actually possible state of the alloys, when required; that is, the object of making the diagram of the iron-nickel system is attained by our investigation.

(3) Since the abnormality observable in the dilatation-temperature curves being due to the A_3 or gamma to alpha transformation, its beginning and finishing points must themselves be the points in question.

(4) It seems to the present authors that the state of the system iron-nickel at high or low temperatures is so clear that at present there remains very little to be desired.

HARDENING BY REHEATING AFTER COLD WORKING

(Continued from Page 220)

gradually less pronounced under the microscope as they heal, whereas they actually become more pronounced. In short, the authors agree with Archer that reactions in the slip planes are responsible for the observed changes in hardness, and they are very glad to point out his priority in saying so. But beyond that, the views diverge. The present authors believe the evidence points to an increase in the thickness of the inter-block layers, for the reasons outlined above. It is true, as stated by Dr. Jeffries, that there is no evidence of new crystallites, but it seems simple to conceive of the whole layer becoming thicker, without necessarily forming new individual crystal units.

Dr. Herty's comments on the properties of oxygenated steels are of interest, being in a new realm of steel considerations. Data on this aspect of the subject are being gathered at the present time.

Mr. Gregg is undoubtedly correct in his reason for the apparent discrepancy in hardness.

The authors are grateful for Dr. Mathews' comments. It was indeed Dr. Mathew's discussion of both phases of the brittleness at 600 degrees Fahr. which prompted much of this work. As Dr. Mathews points out, it is so far as we know merely a coincidence that the temperatures have approximately coincided in the neighborhood of 600 degrees Fahr.(300 degrees Cent).

HIGH TEMPERATURE QUENCHING TREATMENT APPLIED TO COLD HEADING BALL DIES OF PLAIN CARBON TOOL STEEL

By Frank L. Wright

Abstract

The paper describes a high temperature quenching treatment for cold forming dies of plain carbon tool steel, and a submerged water spray quenching fixture used for quenching double end ball heading dies. An increase in quenching temperature from 1470 to 1620 degrees Fahr. followed by a suitable tempering treatment has doubled the life of the dies by increasing their fatigue resistance to or beyond the point where the dies wear or deform large.

The results of endurance tests made on dies from 6 selected bars of carbon tool steel are compared to small variations in chemical analysis, to the normality of the tool steel as determined by the McQuaid-Ehn carburizing test and to the hardness penetration.

Introduction

Annealed chromium-steel ball-wire is sheared and cold upset into ball blanks by automatic machines, as the first operation in the manufacture of high quality steel balls of medium and small diameters. The problem of supplying forming dies to withstand sudden and repeated blows, capable of resisting abrasive wear and permanent deformation, has received attention in many industries. Forming dies for cold heading steel ball blanks may be considered a special case of this general problem and the results of investigations on the composition and heat treatments for this type of die must accordingly be considered special, until they have been tested in other similar applications.

The dies for the cold forming of ball blanks differ from some other cold heading die designs in that a hole is provided for a pin to eject the formed ball, should it stick in the die cavity. This hole through the center of the die for the knockout pin,

A paper presented before the ninth annual convention of the Society held in Detroit, September 19 to 23, 1927. The author, F. L. Wright, a member of the Society, is factory metallurgist with the Atlas Ball Co., Philadelphia. Manuscript received August 1, 1927.

adds to the difficulty of heat treating by introducing an edge close to the bottom of the die cavity, an area of localized stress in quenching and of maximum stress in service. More than this, it sets a limit to the tempering temperature used following the

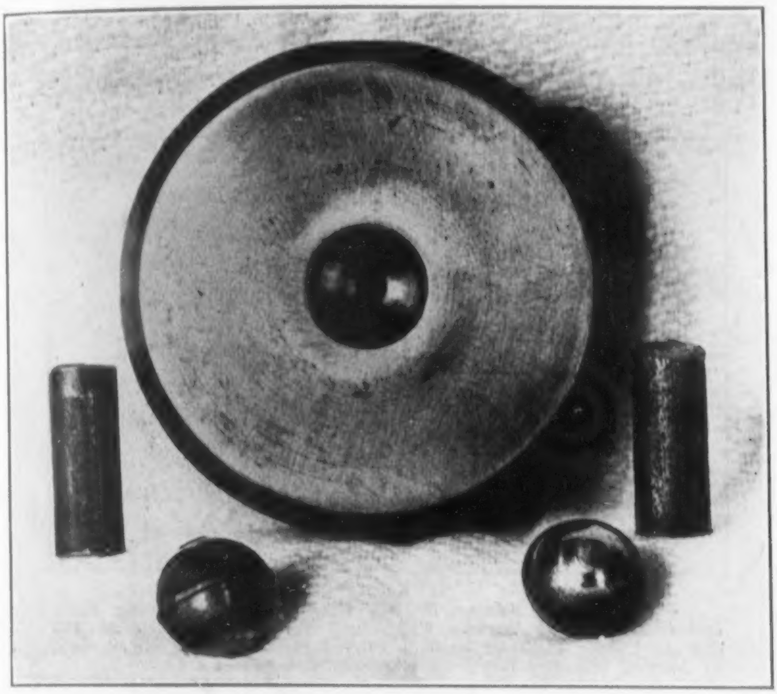


Fig. 1—Cold Heading Die with Sheared Slugs and the Formed Balls made from such Slugs in this Type of Die.

quench, since too much softening in the die cavity from tempering will result in the closing up of the knockout pin hole, with disastrous results if the formed ball sticks in the die cavity.

A forming die for cold heading ½-inch balls is shown in Fig. 1, together with the ball blanks and sheared slugs from which the ball blanks are formed. It is a double end die with identical cavities at either end. The cavities have been lapped smooth and all sharp edges rounded off in order to cut down to a minimum any points of excessive local stressing in service.

The Influence of Alloy Additions on the Type of Failure

Cold forming dies subject to sudden repeated blows under heavy pressure, usually fail in service in three ways, either by wearing or deforming large or by breaking out of metal at the

point in the die cavity where fatigue cracks have formed. The flaking out of metal due to the early occurrence of fatigue cracks, gives much concern when alloy steels of the deep hardening type are used. Cold forming dies of high carbon steel with additions of chromium, chromium and vanadium, chromium and tungsten or manganese and tungsten, all of the deep hardening type of alloy steels, fail quickly, due to the rapid progress of the fatigue

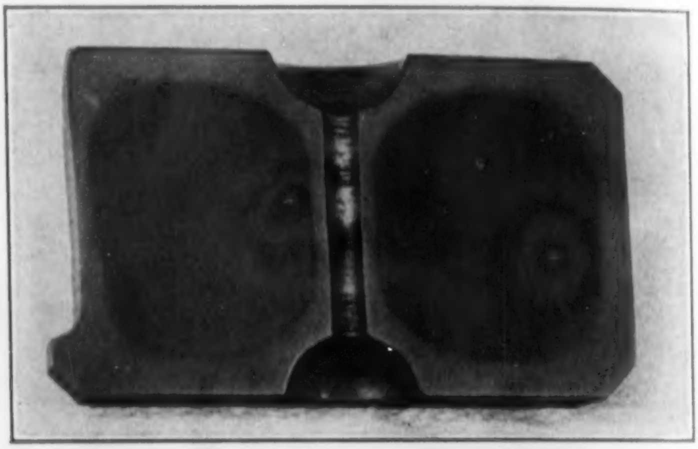


Fig. 2—Cross Section of Die Used for Cold Heading Balls, Quenched at 1620 degrees Fahr. and Tempered 1 Hour at 420 degrees Fahr. Polished Section Etched in 1 per cent Nitric Acid in Alcohol Showing Depth of Hardness Penetration.

cracks into the hard structure. These small flakings serve as starting points for the breaking and splitting open of these deep-hardening steel dies under repeated blows and heavy pressure. This condition of early flaking and splitting of cold heading dies of alloy steel may be relieved somewhat by tempering to a sufficiently high temperature, but then the dies are so softened, that the die cavities quickly lose their shape or close up the knockout pin hole.

Cold heading dies made of plain high carbon tool steels when properly heat treated, have a hard shell with a tough center as shown in Fig. 2. The fatigue cracks starting in the hard shell do not penetrate rapidly into the soft core, so that splitting and cracking open of forming dies made of plain carbon tool steel is a rare occurence. For this reason it has been generally accepted that plain carbon tool steels are best suited for cold forming dies of this type.

A Quenching Fixture for Double End Ball Dies

A special quenching fixture has been devised for use with the double end ball heading dies of carbon tool steels. A sketch of this device is shown in Fig. 3, and is called a submerged water spray quenching fixture. A die is held by thin tongs so that it

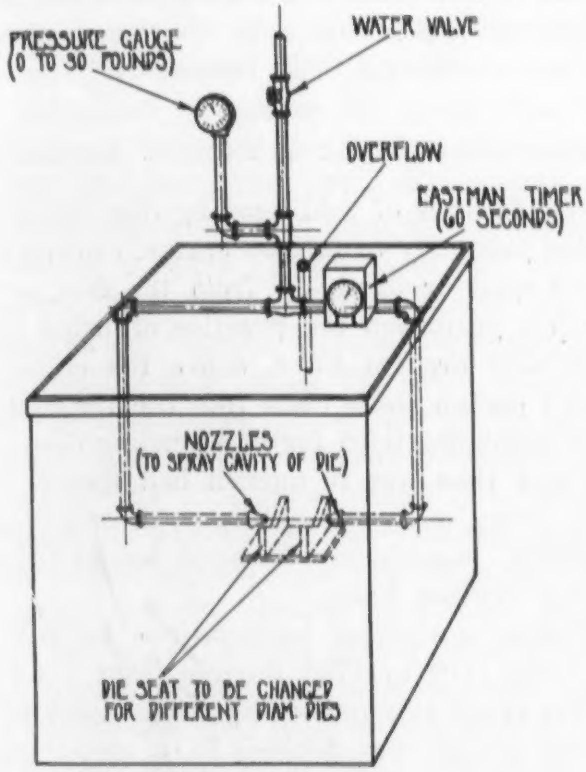


Fig. 3—Sketch of Water Spray Quenching Fixture Used for Quenching Double End Cold Heading Dies.

may be instantly centered between opposite streams of water as it is submerged and placed on the supporting V-block. The stream of water from the water nozzle is allowed to run continuously while the dies are quenched one after the other. A pressure gage on the water line is used to duplicate exact conditions of water spray. The pressure is varied depending on the size of the die cavity. High pressures with small nozzle openings are used for small ball cavities while a large die cavity requires a heavy stream of water from a large nozzle opening, and in this case the water pressure need not be so great.

The die is allowed to remain submerged in the water spray

quench for exact periods of time varying with the mass, and since this time is a matter of seconds only, the heat treater gages the time exactly by means of a timer. The die is steaming as it comes from the water, and is thrown into a tank of warm oil close by to finish the quench. The transfer of the die from the furnace to the fixture and from the fixture to the oil tank is made almost instantaneously. This water-oil quench prevents excessive stresses by not permitting their formation.

High Temperature Quenching Experiments

The early failures of cold heading dies made of carbon tool steels are due primarily to fatigue cracks, causing sections of the hard shell to spall or break off from the face or cavity of the die. Some few years ago the practice of using quenching temperatures 200-250 degrees Fahr. above the critical temperature for plain high carbon steels came into use for cold forming dies, and this treatment was tried for ball heading dies. Our standard practice at that time was to quench ball dies at approximately 1470 degrees Fahr., using the fixture as described and the double water-oil quench, immediately followed by oil tempering for 30 minutes at 430 degrees Fahr.

A number of quenching temperatures for ball heading dies were tried from 1470 to 1720 degrees Fahr. An improvement in die life was noted at a quenching temperature of 1560 degrees Fahr. and the die life was doubled by a quenching temperature of 1650 degrees Fahr. No further improvement in die life was found when temperatures above 1650 degrees Fahr. were used, and the disadvantage of working at higher temperatures made it inadvisable to carry on further tests above 1650 degrees Fahr.

The tempering temperature and the time at the tempering temperature were found to be equally important with the quenching temperature itself, for those dies given the high temperature quench. For ball dies this tempering temperature is limited to the highest possible tempering temperature which may be used and prevent the knockout pin hole from closing up, due to softening of the metal. The tempering temperature most suited for ball dies was found to be 420-430 degrees Fahr. and is critical. Lower temperatures resulted in early failures due to flaking, and higher temperatures to failures due to excessive permanent de-

formation and softening. The time at the tempering temperature was varied and for the mass used in these tests it was found that no appreciable difference in die life resulted when times of more than 1 hour at temperature were used, but shorter times resulted in earlier failure due to flaking.

A check test was made on dies quenched at two temperatures 1470 and 1620 degrees Fahr. all tempered together at 420 degrees Fahr. for 1 hour. The average life of 24 dies quenched at 1470 degrees Fahr., calculated in number of impacts was 17,000. This average die life was increased to 35,000 when the dies were quenched at 1620 degrees Fahr. The average life for the low temperature (1470 degrees Fahr.) quench was determined from 24 tests spread over a range of individual die life from 10,000 to 24,000 impacts. This wide variation in die life between the shortest and longest life, together with an inspection of the failed dies, indicates that the chief cause for early failures and short life is fatigue and subsequent flaking out of the metal.

The endurance tests made on a similar number of dies given the high temperature (1620 degrees Fahr.) quench, did not show this wide variation in life but all the failures came within the range 33,500 to 37,000 impacts. An inspection of the failed dies in this case, shows that the cavities have worn or permanently deformed large before the fatigue cracks have become excessive. The high temperature quench has increased the fatigue life of the plain high carbon tool steel dies, to or beyond the point where the dies fail because of abrasive wear. This limit for wearing large is arbitrarily set for ball heading dies at an increase in weight of the formed ball 3.5-4.0 per cent above the starting size. It should be stated here that the figures for the actual number of impacts cannot be used for comparison with tests made in other applications, because of the arbitrary nature of the end point in these tests.

Endurance Tests Made on Specially Selected Bars of Carbon Tool Steel

It is not the purpose of this paper to show why the life of cold forming dies has been increased through the use of a quenching temperature 250 degrees Fahr. above the critical temperature for plain high carbon steel followed by tempering for a long

period of time at the temperature associated with the breakdown point for austenite, retained on quenching these carbon tool steels. It may be of interest, however, to give the results found on running tests for a number of bars of specially selected tool steel, and to compare these results with the chemical analysis, the structural normality of the steel as tested by the McQuaid-Ehn carburizing test, and finally with some experiments on depth of hardness penetration for ball dies quenched in the spray fixture. The chemical analysis of the bars used in the test together with the normality classification is given in Table I.

These analyses represent steel obtained as plain carbon tool

Table I
Chemical Analysis and Structural Normality Classification for Special Tool Steels Used in Endurance Testing of Cold Forming Dies

Bar No.	C	Mn	Si	S	P	Cr	Va	W	Ni	Normality
A	.94	.24	.22	.010	.018	.07	none	none	none	Normal
B	.95	.35	.22	.011	.020	.02	none	none	none	Partially
C	.98	.22	.22	.006	.009	.04	.20	.04	none	Abnormal
D	.97	.24	.24	.008	.010	.05	none	.17	none	Abnormal
E	1.08	.28	.28	.013	.011	.09	none	none	none	Normal
F	1.02	.23	.23	.007	.013	.03	none	none	none	Abnormal

steel with the exception of "C" a special carbon tool steel containing vanadium. They were selected to show the effect of variation in small percentages of alloys such as chromium on endurance and on the depth of hardness penetration for the high temperature quenching treatment. These bars to be used for test dies were first heated to 1560 degrees Fahr. and quenched in oil and were then annealed by soaking for 8 hours at 1360 degrees Fahr., followed by a slow cooling at the rate of 50 degrees Fahr. per hour to 1000 degrees Fahr. The microstructure produced by this pretreatment was fine granular pearlite. Disks cut from these test bars were normalized by heating to 1750 degrees Fahr. and cooling in air prior to the McQuaid-Ehn carburizing test at 1700 degrees Fahr.

The test dies made from the bars were all heat treated alike. The dies were preheated to 1400 degrees Fahr., transferred to the furnace held at 1620 degrees Fahr., and quenched in the submerged water spray fixture for 15 seconds, finishing the quench in warm oil. A tempering temperature of 420 degrees Fahr. in

oil for 1 hour was used for all test dies. The results of running tests given in the approximate number of impacts is shown in Table II.

In these tests the dies were considered to have failed in service when the ball diameter had increased .007 inch above the starting size, corresponding to an actual increase in weight of

Table II

Average Number of Impacts on Cold Heading Dies Made from Test Bars and Their General Type of Failure. (The Chemical Analysis and Structural Normality is Shown in Table I)

Bar Identification	Type of Failure	Average Number of Impacts Before Failure
A	Large Flakings	30,600
B	Few Small Flakings	37,400
C	Small Flakings	35,800
D	Large Flakings	33,200
E	Very Large Flakings	34,300
F	Medium Size Flakings	35,400

from 3.5 to 4.0 per cent. The failure of the dies was due chiefly to wear although fatigue cracks had formed in every ball cavity. The type and extent to which these fatigue cracks or flakings had progressed were carefully graded at the finish of the test for each bar, and are considered of equal importance with the actual endurance figures.

Influence of Small Amounts of Alloy on the Formation of Fatigue Cracks

The dies made from bars D and E, containing appreciable amounts of scrap alloy, (in the case of D 0.05 per cent chromium with 0.17 per cent tungsten, and E 0.09 per cent chromium) had the greatest number and most serious fatigue cracks resulting in large flakings in the ball cavities. Dies made from bars B, C and F, containing traces of chromium .05 per cent or under, show fewer and less serious fatigue cracks and flakings. The dies made from the steel containing 0.20 per cent vanadium showed the least number of large flakings at the end of the run although the dies made from bar "B", with only 0.02 per cent chromium, showed almost as good condition. These dies with only slight flakings in the cavity might have run for a much longer time had they not worn large to the limit set in general commercial practice of ball heading.

The Influence of Structural Normality of Tool Steel on the Life of Cold Forming Tools

The subject of normality has drawn much attention recently as applied to carbon tool steels. It was of interest, therefore, to determine the structural normality of the various bars used in the running tests, and compare the results with the endurance data. Bars "A" and "E" were considered the most normal showing well defined lamellar pearlite with cementite boundaries at the carburized surface. Bar "B" was partially normal although not quite so well defined as "A" and "E". Bars "C", "D" and "F" were all structurally abnormal, showing pronounced granulation or divorcing of the cementite at the carburized surface. This classification is confirmed by the appearance of the fractures of test dies quenched at 1620 degrees Fahr. The steels classified as structurally normal all showing a coarse and more open structure as compared to the steels classified as structurally abnormal. The finest grained steel both in fracture and under the microscope was the abnormal steel "C" containing vanadium. From the endurance figures and an inspection of the failed dies for fatigue cracks, there seems to be little to choose between the normal and abnormal tool steels for cold heading. Any advantage is with the abnormal steels with their finer grained structures as quenched from the high temperature 1620 degrees Fahr.

Experiments on Depth of Hardness Penetration

The depth of hardness penetration was measured by means of microscopic analysis on specimens prepared from ball dies cut from the 6 test bars and quenched in the special fixture. In addition to the regular ball die section with the hole through the center as shown in Fig. 2, solid ball dies were also quenched in the fixture from 2 temperatures, 1470 degrees Fahr. and 1620 degrees Fahr. The results of these penetration measurements are shown in comparable form in Fig. 4. The lower part of the curve represents the troostite-martensite transition zone, while the upper curve represents the thickness in thousandths of an inch of the completely martensitic shell at the point on the section of least penetration.

It might be expected that the longer life of cold heading

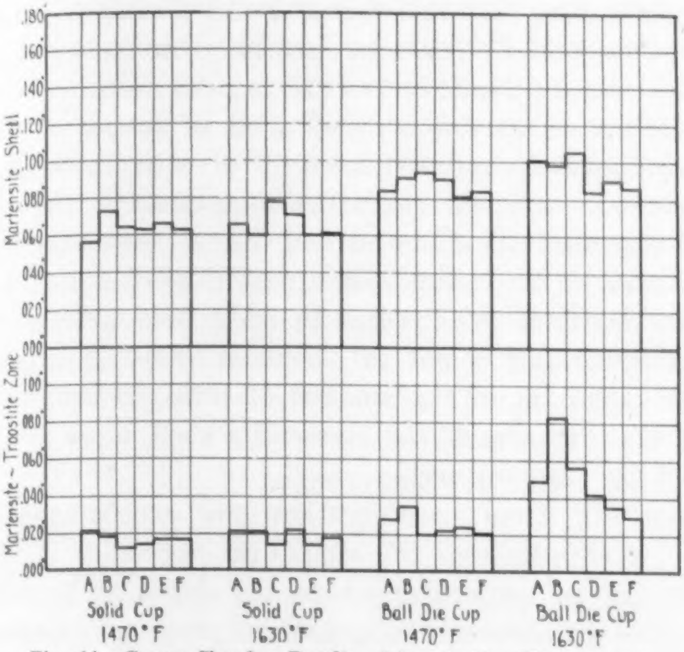


Fig. 4A—Curves Showing Results of Penetration Measurements.

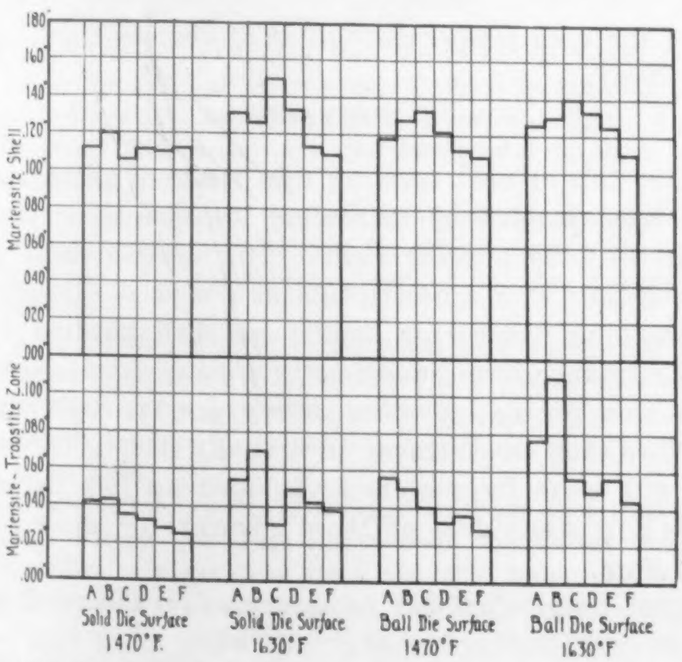


Fig. 4B—Curves Showing Results of Penetration Measurements.

dies given the high temperature quench was due to a great increase in depth of hardness penetration. The actual penetration

measurements show that this is not so and that an increase in penetration of only 10-15 per cent results when the quenching temperature is raised from 1470 to 1620 degrees Fahr.

The effect on hardness penetration of traces of alloys such as tungsten and chromium known to give depth of penetration when present in sufficient quantities were noted in the carbon tool steels. From the tests made on ball dies it is evident that traces of alloys such as chromium and tungsten are not active in influencing the depth of penetration in such large sections or where the speed of cooling is not at a critical rate. It appears, however, that vanadium in the amount of 0.20 per cent has usually increased the thickness of the martensite shell, more so at increasing quenching temperature.

Discounting from consideration the carbon-vanadium tool steel "C" it appears that the structural normality of the carbon tool steels has no marked effect on the depth of hardness penetration. The differences which may be produced in special laboratory tests at critical cooling speeds, do not seem to appear in the actual practice of quenching cold forming dies of carbon tool steel from the high temperature of 1620 degrees Fahr. in a water pressure spray.

Summary

1. The life of cold forming dies made of plain carbon tool steel has been doubled by increasing the quenching temperature from 1470 to 1620 degrees Fahr. The detailed heat treatment is given together with a description of a special submerged water spray quenching fixture for double end ball heading dies.

2. Endurance tests on specially selected bars of carbon tool steel show that for cold heading tools given the high temperature quench, more than small traces of elements such as chromium and tungsten will cause fatigue cracks to open up into flakings much sooner than in steels free of those elements or steels containing only vanadium.

3. Tool steels classified as structurally abnormal according to the McQuaid-Ehn carburizing test, when made into ball heading dies, respond well to the high temperature quenching treatment and were equal if not slightly better than the steels classified as structurally normal.

4. Hardness penetration measurements show that the in-

crease in endurance life cannot be accounted for by the slight increase in penetration resulting from the high temperature quench. The effects on hardness penetration of small traces of chromium and tungsten as well as the effects of structural normality or abnormality seem to be masked by the high temperature quench as applied to ball heading dies.

Acknowledgment is made to the S. K. F. Industries, Inc., for permission to publish this paper, to H. O. Walp of the S. K. F. Research Laboratory for the photographs shown in Figs. 1 and 2, and to the Carpenter Steel Co. for tool steels, specially selected for the hardness penetration tests.

DISCUSSION

A. H. D'ARCAMBAL: There are several questions I would like to ask the author concerning this paper. The first one is regarding the type of fracture. Do you obtain a very coarse fracture? You certainly must obtain at least a slight coarsening of the grain considering the high hardening temperature used.

F. L. WRIGHT: The fracture is not very coarse; but varies with the normality of the steel. The very normal steels do appear very coarse at a quenching temperaure of 1630 degrees Fahr.

A. H. D'ARCAMBAL: I noticed that the chromium varied from 0.02 to 0.09 per cent in the series of steels used. I would be interested in learning just what method you used for making your chromium analysis. I would think it would be pretty difficult for any two laboratories to check that closely, namely, 0.02 to 0.09 per cent.

F. L. WRIGHT: In reply to that I will say those determinations for chromium were the average results from three laboratories. The methods used were two in number, the permanganate method and the bismuth method for oxidizing chromium.

A. H. D'ARCAMBAL: We find in tool steels that they usually contain one-tenth per cent of chromium, due to impurities in the scrap, etc., but it is difficult to check within a few hundredths of one per cent, by the usual methods. Our experience has shown that chromium up to 0.10 per cent does not effect the properties of the steel.

I would also be interested in learning whether you have tried high carbon, high chromium material for these dies, that is, 2.0 per cent carbon, and 12 per cent chromium. It has been tried for other types of dies and I was wondering if you had ever experimented with it for cold heading work.

F. L. WRIGHT: We have tried that type of steel in solid dies. There are certain disadvantages in using alloy, steels. As I mentioned in the first part of the paper, if you have an alloy steel, containing much alloy, in order to maintain the size of the cavity, you dare not temper it very high, and the result usually is that the dies split open and crack. If you temper the high carbon, high chromium steels to a temperature where they will not crack,

they are so soft that they soon lose their shape. The accuracy for cold forming is close.

G. L. KELLEY: I would like to confirm some of the things that Mr. Wright has said out of my own experience. We had occasion to make a hexagonal cap nut, and we encountered similar difficulties. We went through about the same steps in the matter of hardening, settled upon practically the same temperatures. There are some things, however, we did, and maybe Mr. Wright has done them too, that I might add to what he has said.

One thing, we found that severe quenching was very helpful, and in our water quenching we carried water pressures as high as two hundred pounds and found steady improvement up to that point. I thought perhaps that was giving us a greater depth of hardness, and that was the reason for the improvement, so I changed the composition by increasing the manganese in order to get a little greater depth of hardness. That was a complete failure. In the case of dies made of alloy steel, we could make only about five nuts to a die before it cracked. When we used a high carbon tool steel and quenched at the temperatures which Mr. Wright described, we were able to make five thousand nuts to a die, which is the largest we have ever obtained.

R. E. CHRISTIN: I would like to ask the speaker if he tried quenching that die outside of the water, just in the spray, and not submerging the whole die.

F. L. WRIGHT: That practice has been tried, but it is much better to quench the die submerged. The chances for soft spots on account of dripping, air and steam pockets, etc., are such that it is better to quench them submerged.

R. E. CHRISTIN: If you put the spray on the sides so the whole face could be covered with water, would that increase the depth of hardness at the point of application of the work?

F. L. WRIGHT: I doubt it. There is little difference in depth of penetration, either depending on the quenching temperatures or on the type of quenching, whether it is submerged or not.

R. E. CHRISTIN: Also, on this high temperature, did you go so much above the critical point, say 100 or 200 degrees above the critical?

F. L. WRIGHT: We originally used a temperature of 1470 degrees Fahr. for plain carbon tool steel; we later increased that temperature to 1630 degrees Fahr., where we obtain the best results.

R. E. CHRISTIN: Can you remember what that was above the critical temperature?

F. L. WRIGHT: The critical temperature for carbon steels is around 1370 degrees Fahr., so the quenching temperature is about 250 degrees Fahr. above the critical temperature.

R. E. CHRISTIN: We run our dies at from 180 to 200 degrees above the critical, and it varies from 1550 to 1600 degrees Fahr. The carbon content will run from 0.85 to 1.00 per cent.

B. F. SHEPHERD: I would like to ask Mr. Wright what difference in core hardness he found between the dies quenched at the low and at the high temperatures, and I would like to ask Dr. Kelley as to whether he actually

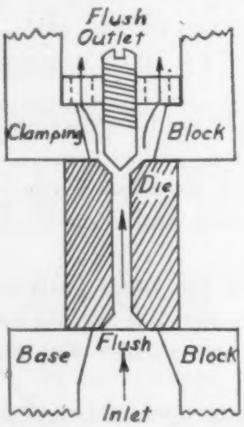
did get any deeper depth of penetration with the 200-pound water pressure and what effect it had upon the hardness of the core.

F. L. WRIGHT: I have made few measurements of the hardness in the core, but I know of some figures which show that if you go far enough in, there is no difference, the hardness in the core is the same.

G. L. KELLEY: We did notice apparently a little greater depth of penetration when we used the high water pressures; the core hardness was about the same. I do not remember the figures, but it made very little difference in that respect.

E. J. P. FISHER: Mr. Wright is to be congratulated for this paper since in the paper he has presented data on this widely used quenching treatment, which data has heretofore not been published for the benefit of those interested.

In this discussion, the writer wishes to mention a special quenching fixture, which had been used to considerable advantage in quenching header



dies, which had impressions at both ends with a knockout hole running through the axis of the die. This special quenching fixture is so constructed that water or brine at high pressure may be forced from one end into the impression at that end and through the knockout hole and past the impression on the other face, without the usual resulting soft spots occurring on the surface of the impression at the further end of the knockout hole, which soft spots are usually due to steam pockets being formed where the stream of coolant bounds over a projection in the die impression. In order to overcome the soft spot effect, the outlet block which is clamped tightly against the further face of the die is equipped with a set-screw baffle, which has a conical shape and which projects into the die impression when the block holding it, is clamped against the face of the die. Thus with this baffle the water or brine being forced against it at high pressure is caused to completely fill the impression of the further end of the die—thus preventing steam pockets and giving efficient cooling of the surface of the impression. This is illustrated diagrammatically in the accompanying figure.

As may be seen from the diagram, that any die quenched in this fixture may be quenched either above or below the surface of the quenching bath.

There are some classes of header dies which give most satisfactory results, when only the impressions are hardened and the body left tough, which can only be accomplished by keeping the coolant away from the sides or body of the die.

The materials used in the construction of the quenching fixture should be of rustless materials and stainless iron has proven to be very satisfactory for the blocks holding the inlet and outlet tubes, as well as for the conical baffle set-screw used in the block at the further end of the heading die. When quenching, the die to be hardened is clamped between the two blocks in such a manner that the die impressions are concentric with the inlet and outlet tubes in the blocks. The die is held rigidly by a spring lever arrangement and the quenching proceeds until all of the red heat has seemingly disappeared from the outside surface of the body of the die, when the die is released and cooled in oil.

F. L. WRIGHT: The time for tempering is usually one hour or more; short times give unsuccessful results and early flaking.

CHAIRMAN J. A. MATHEWS: Have you gone to much longer times than an hour to any advantage?

F. L. WRIGHT: I have seen no difference; there is practically no difference in using times up to four hours.

H. T. MORTON: I have a question I want to ask with regard to small sized dies for eighth inch balls and such sizes. Will they harden through under this treatment?

F. L. WRIGHT: The dies for small balls are not hardened through, the section is sufficiently large so the dies do not harden through.

H. T. MORTON: Do you use smaller size dies for smaller balls?

F. L. WRIGHT: Yes.

H. T. MORTON: Then you never do anything with your worn out dies, do you, you simply throw them away when they sink or fail?

F. L, WRIGHT: That is correct.

H. T. MORTON: Regarding your carbon content, do you use regular 0.95 to 1.05 per cent carbon or does it run from 0.85 to 0.95 carbon?

F. L. WRIGHT: The carbon is 0.95 to 1.05 per cent.

H. T. MORTON: With regard to the nozzle on your spray, is that just the plain type or do you have a special nozzle?

F. L. WRIGHT: The nozzle is tapered. That gives the most efficient spray.

PHYSICAL PROPERTIES OF SEVERAL CHROMIUM-ALUMINUM AND CHROMIUM-NICKEL-ALUMINUM STEELS

By Dr. V. O. Homerberg and I. N. Zavarine

Abstract

A study of the physical properties of steels containing aluminum as an alloying element has received little, if any, consideration in the literature.

The affinity of aluminum for nitrogen in the ammonia case hardening process has resulted in the manufacture of special alloy steels containing aluminum together with chromium or with chromium and nickel. The subjection of these steels to the action of ammonia gas at a comparatively low temperature, results in the production of a very hard surface without deformation of the material and without any subsequent heat treatment.

The present paper gives the results of an investigation of the physical properties of three steels containing aluminum.

Introduction

THE work of various investigators, notably Dr. Fry of the Krupp Works in Germany, in studying the effect of combined nitrogen in steel, has resulted in the introduction of a new series of alloy steels. In most of these studies, ammonia was used as the medium through which the nitrogen was introduced into the material.

Extreme surface hardness can be obtained by subjecting alloy steels containing aluminum together with chromium or with chromium and nickel, to the action of ammonia gas for a period of a few hours to over 100 hours, the time being dependent upon the depth of the desired case. The material to be case hardened by ammonia or "nitrided," as the process is termed, is maintained at a temperature of approximately 900 degrees Fahr. during the

A paper presented before the ninth annual convention of the society held in Detroit, September 19 to 23, 1927. The authors, who are members of the society, V. O. Homerberg is assistant professor in metallography and I. N. Zavarine is instructor in heat treatment at the Massachusetts Institute of Technology, Cambridge, Massachusetts. Manuscript received August 10, 1927.

entire operation, after which it is slowly cooled to room temperature, preferably in an atmosphere of ammonia gas. Great surface hardness is obtained thereby without any subsequent heat treatment. No deformation of the material takes place during this nitriding operation provided that all strains, resulting from the preliminary heat treatment and from the machining operations, have been removed before the subjection of the parts to the action of ammonia.

Since the application of nitrogen to the surface hardening of these special steels is becoming increasingly prominent, it was deemed advisable to make a study of these steels containing aluminum in order to determine the physical properties of the core of the nitrided material. The object of this investigation was therefore to determine the physical properties of these special steels in the heat treated condition before nitriding. Three steels containing aluminum as made by the basic electric process were investigated. The composition of each steel is given in Table I.

Table I
Analyses of Steels

Steel No.	1 Per Cent	2 Per Cent	3 Per Cent
Carbon	0.09	0.44	0.33
Manganese	0.76	0.50	0.68
Silicon	0.28	0.34	0.21
Aluminum	1.01	0.84	1.30
Chromium	1.47	1.61	1.58
Nickel	None	None	1.39
Sulphur	0.022	0.020	0.014
Phosphorus	0.015	0.014	0.017

Preliminary Quenching Experiments

Specimens of each steel, $\frac{3}{4}$ inches in diameter by $2\frac{1}{4}$ inches long, were quenched in oil after heating for 1 hour at the indicated temperature. The specimens were broken and the fractures examined. The Brinell hardness values were then determined. Table II gives the results of these preliminary experiments. No coarsening of the grain structure was evident in steel No. 1 between the quenching temperatures of 1550 and 1900 degrees Fahr. inclusive. The same observations were made on steel No. 2 between 1550 and 1900 degrees Fahr. inclusive and steel No. 3 between

1550 and 1800 degrees Fahr. inclusive. As a result of these preliminary tests these steels apparently have a wide range for heat

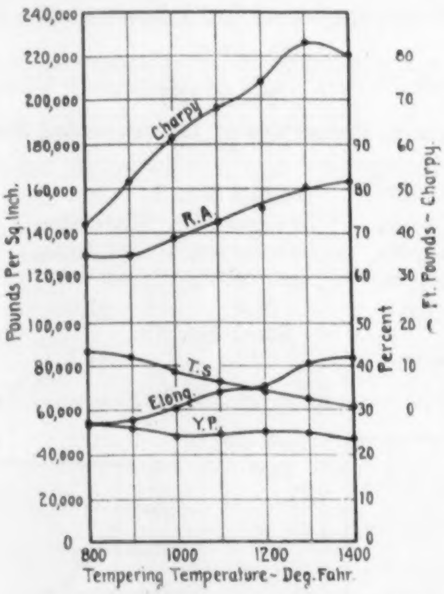


Fig. 1—Curves Showing Physical Properties of Steel No. 1—Specimens Quenched in Oil from 1700 Degrees Fahr. Steel Analysis: Carbon 0.09, Manganese 0.76, Silicon 0.28, Chromium 1.47, Aluminum 1.01, Sulphur 0.022, Phosphorus 0.015.

treatment without producing a coarsening of the grain structure. In this respect, they resemble the chromium-vanadium steels.

Table II
Brinell Hardness Numbers as Related to Quenching Temperature

Quenching Temperature (degrees Fahr.)	Steel No. 1	Steel No. 2	Steel No. 3
As Received	127	180	190
1500	187	415	415
1550	205	480	425
1600	205	550	480
1650	205	550	490
1700	210	550	490
1750	210	550	480
1800	205	550	480
1850	205	550	...
1900	205	550	...

Tensile and Charpy Tests

Tensile specimens 0.505 inches in diameter by 2 inches in

gage length and the standard small Charpy specimens were quenched in oil after heating for 30 minutes at the quenching temperature and then tempered for 1 hour at the indicated tempera-

Table III
Physical Properties of the Annealed Steels

Yield Point, lbs. per sq. in.	Maximum Stress, lbs. per sq. in.	Elongation in 2 inches, per cent	Reduction of Area, per cent	Charpy, ft. lbs.	Brinell Hardness
		Steel No. 2			
56,250	99,500	28.0	67.0	15.6	180
		Steel No. 3			
64,250	97,250	22.5	41.5	6.1	190

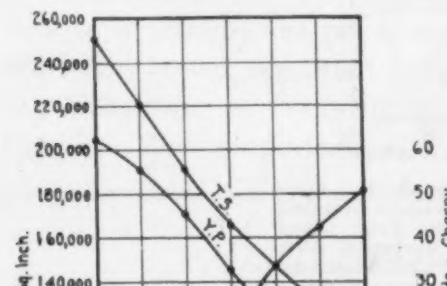


Fig. 2—Curves Showing Phyiscal Properties of Steel No. 2—Specimens Quenched in Oil from 1650 Degrees Fahr. Steel Analysis: Carbon 0.44, Manganese 0.50, Silicon 0.54, Aluminum 0.84, Chromium 1.61, Sulphur 0.020, Phasphorus 0 014.

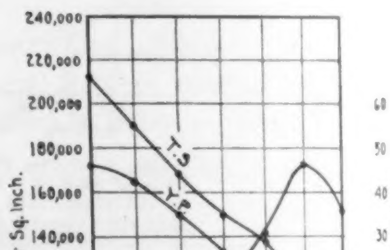


Fig. 3—Curves Showing Physical Properties of Steel No. 3—Specimens Quenched in Oil from 1650 Degrees Fahr. Steel Analysis: Carbon 0.33, Manganese 0.68, Silicon 0.21, Chromium 1.58, Aluminum 1.30, Nickel 1.39, Sulphur 0.014, Phosphorus 0.017.

ture. Steel No. 1 was quenched from 1700 degrees Fahr. and Nos. 2 and 3 from 1650 degrees Fahr. Two specimens were broken in each case, the Brinell hardness determinations being taken at the ends of the tensile specimens.

The physical properties of steels Nos. 2 and 3 in the annealed condition are given in Table III while the physical properties of

the heat treated specimens are given in Table IV and in the accompanying curves.

Table IV
Physical Properties of Heat Treated Specimens

Tempering Temperature (° F.)	Yield Point, lbs. per sq. in.	Maximum stress, lbs. per sq. in.	Elongation in 2 inches, per cent	Reduction of Area, per cent	Charpy, ft. lbs.	Brinell Hardness
STEEL No. 1 Previously oil-quenched from 1700 degrees Fahr.						
800	54,300	86,000	27.0	65.0	41.7	187
900	52,000	84,000	27.5	64.5	51.5	187
1000	47,800	77,000	30.5	69.5	61.5	170
1100	49,500	72,300	34.0	73.0	68.0	158
1200	50,000	68,800	35.0	75.5	73.7	150
1300	49,500	65,300	40.5	80.5	83.0	147
1400	47,300	61,000	41.5	81.5	80.0	132
STEEL No. 2 Previously oil-quenched from 1650 degrees Fahr.						
800	205,000	252,000	10.3	34.0	9.5	510
900	191,250	220,500	10.5	33.0	10.7	448
1000	171,750	190,750	13.0	40.0	12.0	390
1100	145,500	165,500	15.0	47.0	18.7	350
1200	126,250	148,500	18.0	54.0	34.0	320
1300	106,000	128,000	22.3	58.0	42.4	270
1400	92,500	111,750	25.3	60.5	50.6	240
STEEL No. 3 Previously oil-quenched from 1650 degrees Fahr.						
800	172,500	212,500	10.5	37.0	11.0	445
900	165,000	191,750	12.5	41.0	12.8	400
1000	149,500	168,500	14.0	45.0	14.0	365
1100	131,250	149,000	17.0	49.5	18.8	320
1200	112,000	131,750	20.5	57.0	31.3	285
1300	99,250	119,250	25.0	60.5	46.1	250
1400	68,750	115,750	22.5	44.5	35.4	240

SUMMARY

The results of the tests presented in this paper show that the steels described compare favorably with such structural alloy steels as are used in automotive construction. There is no reason to believe that these steels are suitable only for nitrided articles. They should be considered as a valuable addition to the class of strong structural alloy steels and should find application for such purposes.

In conclusion, the authors wish to express their indebtedness to the Ludlum Steel Co. for furnishing the steels for this investigation.

DISCUSSION

NOTE: **The first question asked concerned the effect on the physical properties of the steel if it were tempered to 1400 degrees Fahr. before nitriding.**

DR. V. O. HOMERBERG: Tempering to 1400 degrees Fahr. is desirable in some instances if relatively high physical properties such as hardness and tensile strength are not required for the core. Such a reheating before nitriding will completely remove machining strains. My experience has been that where there has been warpage or distortion in nitrided articles, it has been caused more than anything else by the fact that the working strains had not been relieved before the nitriding operation.

H. C. KNERR: Will Dr. Homerberg tell us about the effect of higher tempering temperatures on the hardness of the nitride case? Another question, is, in what form does the aluminum occur in the steel?

DR. V. O. HOMERBERG: Do you mean the effect on the hardness of the nitride case as the result of the annealing of the nitrided material above the nitriding temperature? We have annealed specimens of nitrided material at 100 degrees Fahr. intervals from 1000 to 1800 degrees Fahr. inclusive. These specimens were packed in cast iron chips, held at temperature for 6 hours and then slowly cooled. All of the specimens were very hard after annealing. Even the one annealed at 1800 degrees Fahr. retained considerable hardness.

I am glad that Mr. Knerr asked the question concerning the form in which aluminum occurs in the steel. There is a prevalent misconception that the presence of aluminum in steel signifies brittleness. This is very true if the aluminum is present in the steel in the form of its oxide. However, in the process as practiced in making these steels containing aluminum, the oxide passes entirely into the slag and the residual aluminum goes into solid solution in the steel.

F. B. FOLEY: Dr. Homerberg, do you find that while you might not lose any nitrogen, that its form is changed from that of nitrogen in solid solution to iron nitride needles?

DR. V. O. HOMERBERG: If a plain carbon steel is nitrided at 1650 degrees Fahr. and then allowed to cool slowly in the furnace, the iron nitride produced will appear mainly, if not entirely, in the form of needles. In nitriding these special alloy steels, followed by annealing, the nitrided case shows no distinct evidence of the presence of nitride needles even after heating at 1500 degrees Fahr. for 6 hours followed by furnace cooling.

R. S. MACPHERRAN: What penetration do you get?

DR. V. O. HOMERBERG: The depth of penetration is dependent upon several variables, such as temperature, time, and the extent of dissociation of the ammonia. A case depth of approximately 0.03 inch is produced on nitriding at a temperature of 875 degrees Fahr. for 90 hours. It must be remembered that since the hardness of the nitrided case is so much greater than that produced by the common case hardening operations, the wear will be a great deal less in the former instance. The hardness results, as determined by a Herbert Pendulum and converted into Brinell values, on a typical specimen after nitriding for 90 hours at 875 degrees Fahr. are as follows:

Depth in Inches	Brinell hardness
0.000	1002
0.005	999

Depth in Inches	Brinell hardness
0.010	810
0.015	516
0.020	434
0.025	378
0.030	378
0.035	351
0.040	351

E. J. FISHER: I would like to ask Dr. Homerberg if it is necessary to quench from a high temperature after nitriding?

DR. V. O. HOMERBERG: No heat treatment is given to the articles after nitriding. The value of the nitriding process is dependent to a great extent on this fact. The articles are heat treated and finished before the nitriding operation. Since the nitriding is performed at such a low temperature and then followed by slow cooling, very little, if any, warpage or distortion will take place.

DR. W. E. RUDER: I would like to ask Dr. Homerberg about the structure of the internal part of the material which has been nitrided with ammonia; as to whether he has ever observed any nitrogen, either by analysis or under the microscope, inside of the case. I am interested in this because some years ago when we were working on the microstructure of steel containing nitrogen, introduced in the same way, we observed this unusual hardness due to the nitrogen, but at that time it did not appear to us to be a very useful thing because of the embrittlement of the entire section. That leads me to ask Dr. Homerberg if he, or any of the originators of this process, have any theory as to just how the aluminum in this special alloy acts in confining the nitrogen to the surface case if it does.

DR. V. O. HOMERBERG: I have made no chemical analyses to determine the nitrogen content of nitrided material as my observations have been entirely of a microscopic character. In only two cases have I observed the marked brittleness throughout the material after nitriding. In both instances the steel used was of a low carbon content. Marked grain growth had taken place near the surface and the specimens broke sharply with a shiny fracture. No cases of such brittleness have been observed with these special steels having analyses corresponding to steels Nos. II and III of this paper. It would be difficult to determine microscopically the actual depth of nitrogen penetration since the nitride case shows no nitride constituents that have been detected microscopically as far as my investigation has progressed. I believe that the nitride or nitrides are in solid solution in the case. Aluminum has a great affinity for nitrogen so that it probably acts as a carrier. The gradation in the hardness of the nitride case is similar to that produced in the common case hardening process. In the latter instance, a point is reached where the case merges into the core and the limit of carbon penetration is obtained. An analogous process takes place in case hardening with ammonia.

J. S. VANICK: The question has taken a rather peculiar drift from the title of the paper, so that it has become a discussion on nitrogenizing, where I

happen to have had a considerable experience in a rather different type of work. I do not know that much can be added to what has been said, but I would like to correct, at least, from our experience, some of the discussion or some of the statements which the discussion has provoked. One of them, on the matter of case depth, I am quite sure, is due to the temperature at which the nitrogenizing is carried on. That is, at the temperature of 450 degrees Cent., or about 900 to 1000 degrees Fahr., the penetration of nitrogen is very slow and the depth of penetration under such conditions is going to be rather shallow. If that temperature is raised to anything like 1400 or 1500 degrees Fahr., then another change takes place where the penetration is rapid, but there is depending upon the equilibria in the gas phase a decomposition of the nitride freeing nitrogen or, in this case, a decomposition of the ammonia. The resulting reaction, we believe, results in the formation of hydrogen, either through dissociation of the ammonia or through formation and decomposition of hydrogen bearing compounds in the steel formed through contact of hydrogen with carbon, if you please, or with other elements. These reactions produce an intergranular fissuring which, if the equilibrium within the steel is in the proper direction, leaves the steel interior without any trace of nitrogen but leaves fissures within the core that will produce as clean and as brittle a break as anyone would want to see[1].

The matter of the effect of carbon in steel is a case in the same direction; that is, in the presence of carbon, ammonia acting upon the steel first attacks the carbon by again, a preliminary decomposition, then an infiltration of hydrogen, which picks up the carbon and either washes it out or gets it out of the way before the nitrogen can penetrate much further. The presence of carbon there would act to a great extent as a barrier in preventing the deep infiltration of nitrogen.

DR. V. O. HOMERSBERG: Obviously, both nitrogen and hydrogen are produced as the result of the decomposition of the ammonia during the nitriding operation. Although hydrogen in the atomic state, as in this case at the moment of the decomposition of the ammonia, is undoubtedly an active decarburizer, I have noted little if any decarburization in many of the specimens. The equilibrium conditions involving the ammonia gas and its decomposition products, together with the carbon content of the steel, may be important factors. Experimental work is being done along this line.

The fissuring which Mr. Vanick mentions has been noted in only two instances and both occurred in the low carbon material. Marked grain growth was also noted in the nitride case in these two instances.

It must be remembered that the nitriding operation is done at a comparatively low temperature and at atmospheric pressure. Entirely different results may be obtained at higher temperatures and pressure.

[1]TRANSACTIONS, American Society for Steel Treating, vol. IV, 1923, p. 62. Also TRANSACTIONS, American Society for Steel Treating, vol. XII, 1927, p. 169.

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

THE CONSTITUTION OF STEEL AND CAST IRON SECTION II—PART II

By F. T. Sisco

Abstract

The present installment, the second of the new series, discusses the annealing operation. This is taken up in three steps: (1) heating the material to the annealing temperature (2) holding the steel at the proper temperature and (3) cooling from the annealing temperature. In each of these steps the various structural changes taking place are discussed. The operation of annealing as discussed in this installment is a description of that process as it involves heating to a temperature above the critical range. Annealing below the critical range, annealing cold-worked steel, spheroidizing and normalizing will be described in the next chapter.

ANNEALING is a form of thermal treatment that is applied, at some step during the processing, to much of the tonnage of hot and cold worked steels and castings. Practically all alloy and tool steels are annealed before being worked or machined into final form. In the manufacture of wire and other cold drawn or cold-rolled material annealing is usually necessary to permit cold working operations to be completed satisfactorily. In general we may say that an annealing of some sort is necessary on steels used for special purposes, as distinguished from the great mass of tonnage material which goes into rails, sheet, plate, structural members and the like and which is ordinarily used in construction without thermal treatment. The commercial an-

This is the twelfth installment of this series of articles by F. T. Sisco. The several installments which have already appeared in TRANSACTIONS are as follows: June, July, August, September, November, 1926; January, February, April, June, August, October, 1927.

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nealing of rolled, forged and drawn material has for its object: (1) to make the steel soft and easily machined, (2) to increase ductility and toughness, (3) to refine the grain, and (4) to remove internal strains due to hot and cold working. Steel castings are annealed primarily to remove casting strains and refine the grain.

Most of the alloy steels and practically all of the high carbon steels must be annealed before they can be machined readily and economically. Hot working is often responsible for considerable heterogeneity of structure. Annealing will refine the grain and eliminate much of this.

Annealing is of necessity a part of practically all cold working processes, especially where cold working is severe as in wire drawing. This form of mechanical work increases the strength and reduces the ductility rapidly. In many operations—wire drawing for example—frequent annealing is necessary to remove the brittleness so that the drawing operations can be carried further.

In the manufacture of iron and steel castings, severe internal strains are set up when the metal solidifies in the mold. This is especially true where adjoining thick and thin sections are present in the casting. Annealing will, in a great measure, remove casting strains and will improve the properties by grain refinement.

In the annealing of iron and steel three steps are necessary: (1) heating the steel to the proper temperature, (2) holding at this temperature for the proper time and (3) cooling from the annealing temperature down to normal. In studying the constitutional changes in annealing we will look first of all at the structural condition of the steel before annealing and then at the changes taking place when the steel is heated, while it is at the annealing temperature, and finally during cooling.

Heating the Steel to Annealing Temperature

In brief, heating for annealing consists in placing the material in a suitable furnace and applying the heat uniformly until the charge is at the proper temperature.

In general, before annealing, the steel may be in almost any structural condition; it may be pearlitic, sorbitic, troostitic or

martensitic; it may be partly hard and partly soft; and may vary in structure and properties from end to end or from surface to center of the piece. The structural and physical condition of the steel before annealing is not of great importance; as a rule annealing destroys all vestige of the original structure. In this connection, however, Jefferies calls attention[12] to the fact that a steel having a large grain structure at atmospheric temperature will have, when heated through the transformation range, a larger austenite grain than one with a small grain size. This, however, is of relatively minor importance.

As an example of the structurally heterogeneous material which is commonly annealed, the following may be noted: (1) rolled sections of air hardening and other alloy steels and rolled or forged tool steels which may be extremely hard on the surface of the bar and soft in the center; (2) castings of irregular section which may be fine-grained in the thinner sections and coarse-grained in the thicker parts; (3) cold-rolled or cold drawn material in which the original grain has been severely distorted and elongated by the rolling or drawing operation; (4) hardened material in almost any structural condition, which for some reason must be heat treated again; (5) hot-rolled or hot-forged steels in which the finishing temperature had fallen below the critical range; and many others. Annealing is used for all of these classes; in some it is necessary solely to homogenize the structure.

For annealing, the steel is heated just above the critical range, and held long enough for the structural changes to take place. One exception to this is steel castings which are ordinarily heated to a temperature considerably above the critical range in order to break up the existing structure, or in lieu of this must be held at a temperature just above the critical range for a much longer time.

Fig. 11 shows the iron-carbon diagram and heat treatment ranges.[13] Fig. 11 shows the annealing temperatures for all of the carbon steels. This ranges from 25 to about 75 degrees Fahr. above the upper critical point. From this diagram and from the knowledge gained in earlier installments we can trace the changes taking place in heating our steel to the annealing temperature.

[12]Cited in Part I this series; TRANSACTIONS, American Society for Steel Treating, October, 1927, p. 665.

[13]From American Society for Steel Treating HANDBOOK, page N5.

In this discussion we will assume that the steel at atmospheric temperature is in its normal condition, that is, cooled slowly after hot working so that all structural changes have taken place in their regular order. For the first example we will take a 0.20 per cent carbon steel which at atmospheric temperature will consist of 23.4 per cent pearlite and 76.6 per cent free fer-

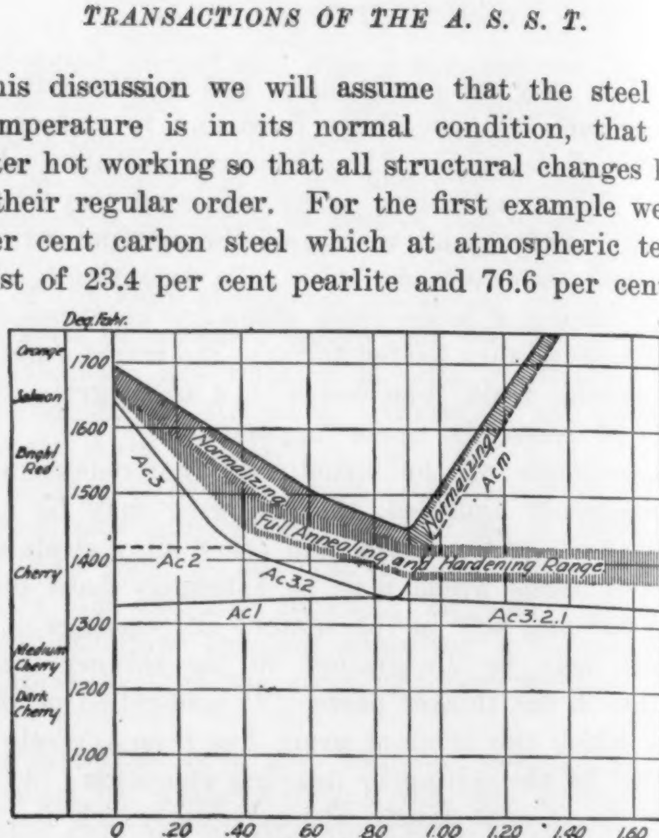


Fig. 11—Iron-Carbon Diagram Showing Temperature Ranges for Heat Treatment.

rite or 97 per cent total ferrite and 3 per cent total cementite. As we heat this steel gradually no structural change will take place until a temperature of approximately 1325 degrees Fahr. (720 degrees Cent.) is reached. At this point, Ac_1, the pearlite changes to the solid solution austenite of eutectoid composition. As the heating is continued this austenite starts to absorb the pure iron which goes through the successive allotropic changes of alpha, to beta (?) to gamma iron. Above the Ac_3 point, which for this steel is about 1520 degrees Fahr. (825 degrees Cent.), the steel consists wholly of the solid solution austenite.

In the case of a 0.40 per cent carbon steel which contains 46.8 per cent pearlite and 53.2 per cent ferrite there is no change until the temperature reaches the Ac_1 point, or 1330 degrees Fahr. (720 degrees Cent.). At this temperature the pearlite changes to austenite of eutectoid composition. This austenite in turn absorbs the free ferrite until at 1420 degrees Fahr. (770 degrees Cent.), Ac_{3-2}, all the changes have been complete and

the steel consists wholly of austenite, the solid solution of carbon in gamma iron.

With an 0.85 per cent carbon steel there is no structural change in heating until 1330 degrees Fahr., the Ac_{3-2} point, is reached. At this temperature the pearlite which is already of eutectoid composition changes to austenite.

From Fig. 11 and from what we have just stated it is evident that in heating for annealing (and for hardening as we shall see later) there is no structural change taking place[14] until the lower critical point is reached. In addition structural changes are not complete until the upper critical point for that particular steel is passed. According to this, we can take any steel which is in its normal state at atmospheric temperature and heat it to any temperature below the critical point repeatedly, and cool it from this temperature, rapidly or slowly as we desire and there will be no structural change and hence no change in properties. In addition in order to anneal steel satisfactorily we must heat the material sufficiently above the upper critical point so that we are sure that the structural changes will take place completely and rapidly and will not be influenced by the possibility of lag.

From Fig. 11 it is evident that the annealing temperature varies with the carbon content. For steels containing less than 0.75 per cent manganese the American Society for Testing Materials recommends the following temperatures:

less than 0.12 per cent carbon—1600 to 1700 degrees Fahr.
0.12 to 0.30 per cent carbon—1550 to 1600 degrees Fahr.
0.30 to 0.50 per cent carbon—1500 to 1550 degrees Fahr.
0.50 to 1.00 per cent carbon—1450 to 1500 degrees Fahr.

In commercial annealing the cold charge is placed in a relatively cool furnace. Charge and furnace are then heated to the annealing temperature. The time for heating is determined largely by the size of the charge and the design of the furnace, in other words, by experience. The charge should be heated as rapidly as possible, taking care, however, that no part of the charge becomes overheated.

Steel absorbs heat faster, the higher the temperature of the

[14]This of course assumes that the steel is in a stable or normal condition, i. e., pearlite and ferrite, and has not been cold-worked. If the steel has been hardened, even slightly, changes in structure will take place at relatively low temperatures.

heating chamber. Portevin[15] has shown that a steel cylinder measuring 30 millimeters in diameter placed in a furnace heated to 1000 degrees Cent. will reach that temperature in nine minutes; but that twelve minutes were necessary for a similar piece to reach the maximum temperature in a furnace heated to 800 degrees Cent.

Holding Steel at Annealing Temperatures

After the steel has been heated to the proper temperature it is necessary to hold it at this temperature until it is heated through uniformly. The time necessary is again a function of the size of the charge, the design of the furnace and in addition the temperature itself, and is determined largely by experience. Theoretically a piece 12 inches thick should be heated uniformly in one hour.[16]

In the previous installment we discussed austenite grain growth above the critical range. It was shown that the two principal factors in this grain growth were temperature and time. "Grain growth is promoted by a high temperature, the higher the temperature above the critical range, the more rapid the growth. Grain growth is also proportional to the time. If the temperature remains constant, the longer the time at temperature the greater the growth."

This has been shown graphically in Fig. 12 from Sauveur.[17] The horizontal band represents the critical range. In I, the steel has been heated to some temperature below the critical range. It cools from this temperature unchanged. In III, the steel has been heated just above the critical range. In this case cooling results in a fine structure. In II, the steel has been heated to a high temperature. The result is a coarse structure.

Although Jeffries states[18] that the grain size of a steel cooled from above the critical range is not inherited from the mother austenite, it is generally known in commercial heat treatment that a coarse brittle structure almost always results from overheating

[15]Cited in Sauveur, Metallography and Heat Treatment of Iron and Steel, 1926, p. 192.

[16]Heat Treatment Committee, A. S. T. M.

[17]Loc. Cit., p. 190.

[18]Cited in first installment of Section II, TRANSACTIONS, American Society for Steel Treating, October, 1927, p. 663.

in annealing. Much otherwise good steel has been spoiled for this reason. It is possible, however, in many cases to re-anneal overheated steel and produce a satisfactory product.

We can summarize the effect of holding the steel at the annealing temperature by saying that after the steel has been heated

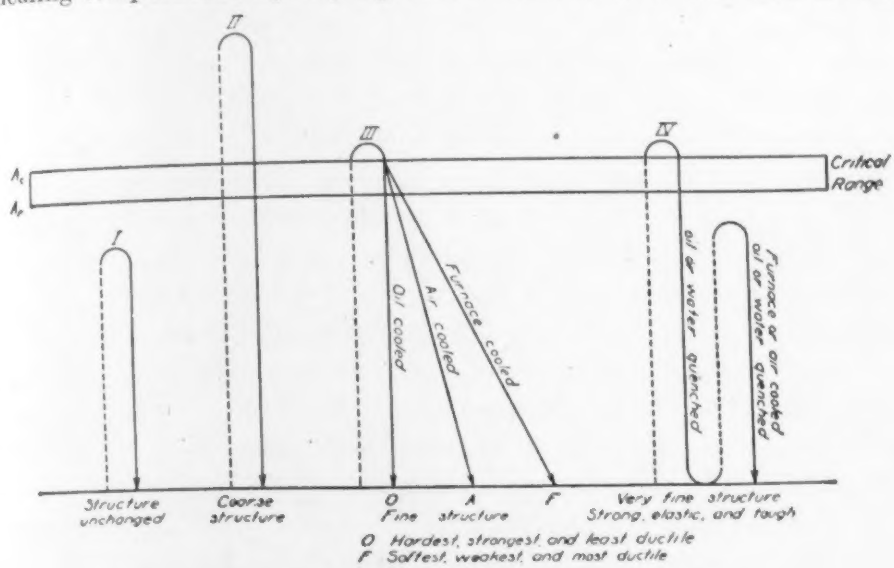


Fig. 12—Diagram Illustrating the Annealing of Steel. (Sauveur).

through the critical range, no structural change takes place except a gradual coarsening or grain growth which is dependent upon the temperature, the time and several minor factors.

The next step in annealing is cooling[19] from the annealing temperature.

Cooling From the Annealing Temperature

When we think of the annealing of steel we ordinarily think of a softening operation. Commercial annealing is usually this, and this only. In fact most of the steel now annealed is put through this treatment primarily so it will be soft enough to machine readily and economically. To make steel soft we usually heat it to some temperature just above the critical range and then cool it as slowly as possible. When steel is cooled very slowly all of the structural changes which normally should take

[19]The discussion thus far has concerned only the mechanism and structural changes of annealing just above the critical range Normalizing, and annealing cold-worked material will be discussed in a subsequent chapter.

place, do so in their regular order and the structure approaches a condition of stable equilibrium.

Above the critical range the structure is austenite, a solid solution of carbon or iron carbide in gamma iron. As we discussed in a former installment, when steel cools, at the upper critical point the allotropic transformation of the gamma iron to alpha iron begins. As this transformation proceeds the alpha iron, having practically no solvent powers for carbon rejects the iron carbide. Thus as the material cools iron carbide or carbon, as the case may be, concentrates in the remaining gamma iron until, when the lower critical point is reached, the remaining austenite now of eutectoid composition is transformed to pearlite.

The structural change taking place at the critical range thus involves two steps, to wit: (1) the allotropic change of the ferrite and a resulting tendency for it to segregate into individual grains and (2) the gradual concentration of the iron carbide until the remaining austenite is of eutectoid composition, and, finally the change of this austenite into pearlite.

Now that we understand clearly just what happens when the steel is cooled through the critical range we can view for a moment the effect upon the structure of varying rates of cooling. If we retard the cooling as much as possible, until it is almost infinitely slow, the change to stable equilibrium will be practically complete. All of the free ferrite present will tend to segregate into grains, provided enough of this constituent is present; and the pearlite will assume the form of distinct laminations, almost parallel plates. Figs. 13 and 14 show the pearlite in this form.[20] Fig. 13 is the structure of a high carbon steel cooled very slowly so that stable equilibrium has been nearly attained. Fig. 14 shows these parallel plates of ferrite and cementite at higher magnification. In these two specimens no free ferrite was present.

It should be remembered in connection with slow cooling from the annealing temperature that cementite is only relatively stable. We have discussed this under the constitution of cast iron where it was shown that cementite tends to break up into iron and graphite. In the case of very large steel sections it is possible to cool so slowly that this tendency of the cementite to

[20]Photomicrographs by J. L. Hester, photographer and metallographer, Wright Field.

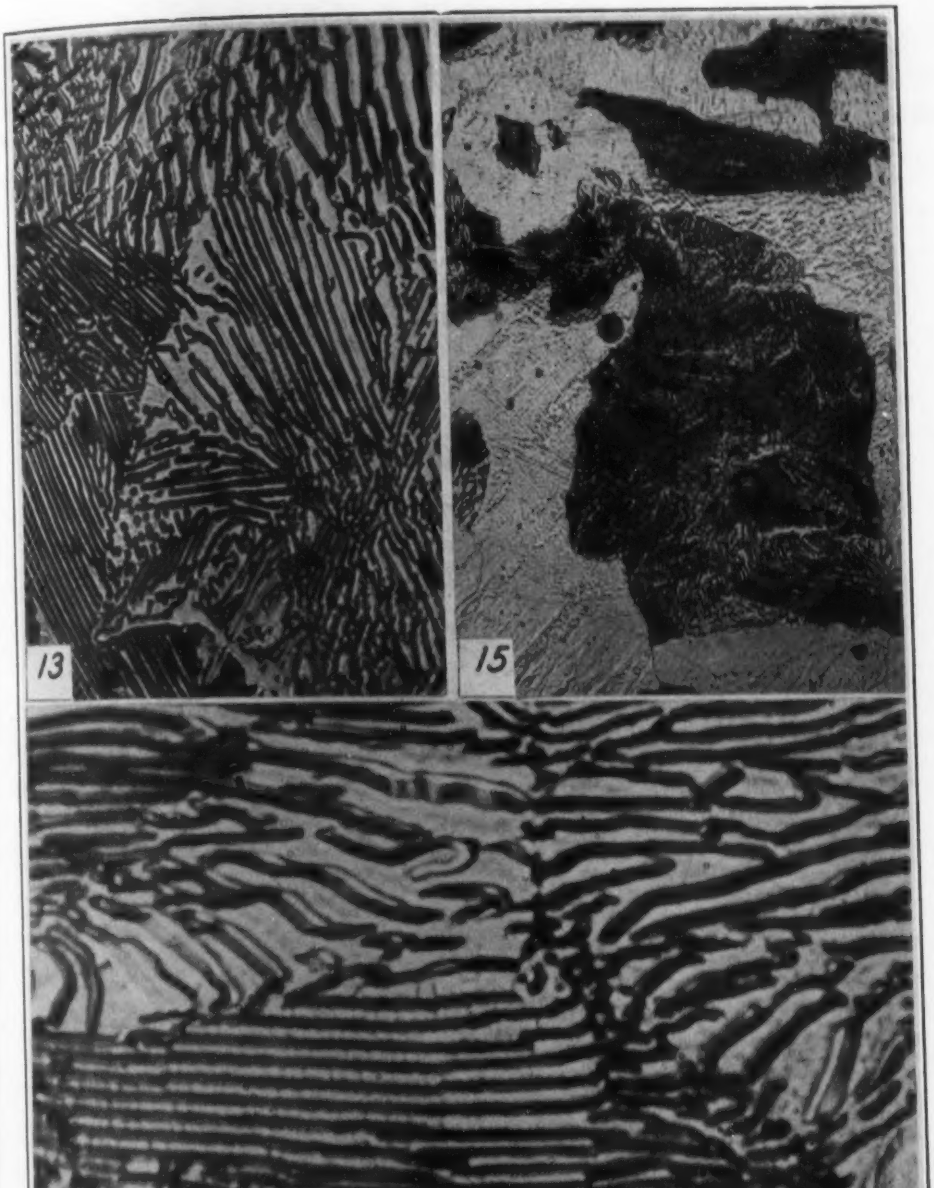


Fig. 13—Photomicrograph of 0.80 Per Cent Carbon Steel Showing Laminated Pearlite. Mag. 1000X. Fig. 14—Photomicrograph of 0.90 Per Cent Carbon Steel Showing Laminated Pearlite. Mag. 3000X. Fig. 15—Photomicrograph of 0.25 Per Cent Carbon Steel Showing Pearlite Partially Laminated, Partially Granular, (Dark) and Free Ferrite (Light). Mag. 1000X. All Specimens Etched in Alcoholic Nitric or Alcoholic Picric Acid.

attain a still more stable condition is manifested by a partial breaking up of the lamellae. When this pearlite has been coarsened and the lamellae broken up by very slow cooling it is known as divorced pearlite. Usually there is evidence in the structure that laminations originally existed. In general, divorced pearlite is comparatively rare, in any case it is not nearly as frequent an occurrence as the lamellar variety shown in Figs. 13 and 14.

If the cooling is not quite so slow, the plates usually are not so regular in appearance, but assume a more or less curved or curly, somewhat broken appearance. Frequently the cementite and ferrite plates become so indistinct that they are scarcely resolvable. This condition is shown in Fig. 15 and at high magnification in Fig. 16. Fig. 15 is the structure of a 0.25 per cent carbon steel. The free ferrite is clearly predominant in the structure. Fig. 16 at 3000 diameters shows pearlite in which the lamellae are relatively indistinct, in some parts of the specimen unresolvable.

In general when cooling has been so accelerated that the pearlite is mostly granular, ferrite, if this constituent is present, is not always clearly distinguished by microscopic examination. Time has not been available for this excess constituent to free itself completely and segregate into individual masses or grains. Considerable of the free ferrite will remain entrapped with the pearlite and in many cases will be hardly distinguishable from this aggregate. This is usually the case when the structure is apparently all granular pearlite. Fig. 17 shows a 0.30 per cent carbon steel in which cooling has been slightly accelerated. If this structure is compared with Fig. 15, it will be at once apparent that not nearly so much ferrite is evident in Fig. 17 as in Fig. 15 even after allowing for the difference in magnification.

If cooling from the annealing temperature is still more accelerated, we get a condition bordering on unstable equilibrium. No laminated pearlite can be detected, and in most cases no free ferrite is evident even though considerable is present. This structure, shown in Fig. 18, is known as sorbite. Sorbite is usually associated with the transition constituents in hardened and tempered steel and so will be discussed more properly in a later chapter.

Before summing up the structural changes taking place in the annealing operation, we should say a word or two explanatory

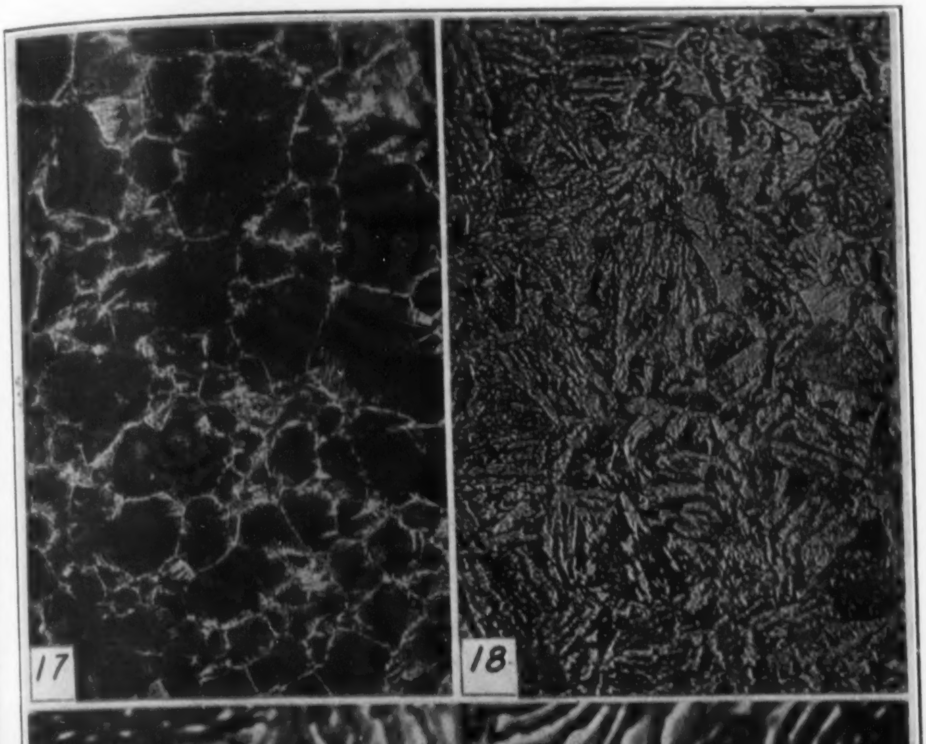


Fig. 16—Photomicrograph of 0.90 Per Cent Carbon Steel Showing Pearlite Partially Laminated and Partially Laminated and Partially Granular. Mag. 3000X. Fig. 17—Photomicrograph of 0.27 Per Cent Carbon Steel Showing Granular Pearlite and a Small Amount of Free Ferrite. Mag. 500X. Fig. 18—Photomicrograph of a 0.30 Per Cent Carbon Steel, Sorbite, Mag. 500X. All Specimens Etched in Alcoholic Nitric or Alcoholic Picric Acid.

of the term "slow cooling". This term ordinarily signifies furnace cooling in commercial tonnage annealing. In laboratory annealing and in the annealing of small charges or single pieces we have to take into consideration the size of the piece, the size of the furnace and other factors. For example the cooling of a small bar in a small furnace may be as rapid as that of a large bar cooled in air. Similarly a small bar cooled in air may cool no faster than a large bar quenched in oil.

In the discussion of the structural changes in cooling steel from the annealing temperature we have considered, as we did in past installments, that steel was a relatively pure alloy of iron and carbon. The presence of considerable amounts of other elements may have an appreciable influence on these structural changes. For example silicon tends to promote the formation of lamellar pearlite, and in large amounts accelerates the divorce of the pearlite. In steels containing high percentages of silicon (2.00 to 4.00 per cent) this tendency is carried so far that graphite is often formed in annealing. On the other hand manganese and some of the alloys notably nickel and chromium have a tendency in the opposite direction. These elements retard the transformation of austenite and the divorce of pearlite.

It should be understood that these described structures resulting from different cooling rates are typical only. In every steel some segregation of the cementite and ferrite occurs. Often it is possible to find divorced pearlite, lamellar pearlite, granular pearlite and even sorbite in the same piece. Even the lamellar pearlite appears differently in adjacent areas as is evidenced from Fig. 13. The micrographs shown in Figs. 13 to 16 are, however, fairly typical of the structures encountered in daily examination of annealed steels.

Summary

In this elementary discussion of annealing we followed the structural changes in heating the material to the annealing temperature and the structural changes accompanying the cooling again to atmospheric temperature. We noted that ordinarily the steel may be in any structural condition before annealing and that heating to above the critical range usually destroys all vestige of the pre-existing structure. We traced the actual change in structure occurring when a normal steel consisting of pearlite

or pearlite and free ferrite was heated to a temperature just above the critical and viewed the possibility of grain growth occurring above the range.

It is evident from the discussion in the preceding section that the speed of cooling from the annealing temperature has a great influence on the resulting structure and of course, on the properties. This was well illustrated by the photomicrographs. In general very slow cooling results in a nearly stable condition, namely: laminated pearlite consisting of fairly large, regular and parallel plates of ferrite and cementite and distinct patches, even grains, of free ferrite if the constituent is present in appreciable amounts. If cooling is not quite so slow a condition of stable equilibrium is not fully attained. In this case the laminations or plates of ferrite and cementite are not so distinct and may even appear granular. In addition the free ferrite present may not be segregated so as to be clearly evident under the microscope.

Having viewed these normal structural changes taking place in annealing we have paved the way for a discussion of the mechanism of annealing after cold working, annealing steels of varying carbon content, alloy steels, etc., and normalizing and spheroidizing. This we will take up in the next installment.

Abstracts of Technical Articles

Brief Reviews of Foreign Publications of Interest To Metallurgists and Steel Treaters

ON THE MAGNETIZATION OF SINGLE CRYSTALS OF IRON. By Kotarô Honda and Seiji Kaya. *Kinzoku no Kenkyu*, Vol. IV, No. 1, p. 1-24.

The present paper contains the result of the magnetic measurements made on three oblate ellipsoids of single crystals, 20 millimeters in diameter and 0.5 millimeters in the shortest diameter, the flat planes of the ellipsoids coinciding with the planes (100), (110) and (111) respectively. The magnetization curves for the principal axes, as well as the parallel and perpendicular components of magnetization were measured by the ballistic method. The characteristic features of the magnetization curves are as follows:

(a) The magnetization curves in the direction of the tetragonal and digonal axes are almost straight up to an intensity of magnetization of about 1000 C. G. S. units, and that in the direction of the trigonal axis up to 700 units.

(b) Then these curves twice show sharp breaks or bendings.

(c) The saturation of magnetization is much more easily attained than in the case of polycrystals, its value amounting to 1715. In the direction of the tetragonal axis, the saturation is reached at 70 gausses only, and in those of the digonal and trigonal axes at 500 and 450 gausses respectively.

(d) In the plane (100), the direction of the tetragonal axis is more easily magnetizable than that of the digonal. In the plane (110), the directions of the tetragonal, digonal and trigonal axes are in a decreasing order of magnetization.

(e) In the plane (111), the space-lattice consist of a series of equilateral triangles. Below a field of 280 gausses, the direction of the sides of the triangles is more magnetizable than that of the bisector of the triangles; but above the field, the contrary is the case.

Next the field was kept constant and the orientation of the crystals varied; the components of magnetization parallel and perpendicular to the field were thus measured. The characteristic features of these curves are as follows:

(a) In the plane (100), both parallel and perpendicular components of magnetization vary with a period of 90 degrees. For the parallel components, the direction of the tetragonal axis has the maximum magnetization, and that of the digonal the minimum magnetization; but for the perpendicular component, the magnetization vanishes in the direction both of the tetragonal and digonal axes and attains a maximum or minimum between them.

(b) Below a field of 10-20 and above 500 gausses, the magnetization is independent of the direction of the field.

(c) In the plane (110), these two components of magnetization vary with a period of 180 degrees. For the parallel component, the principal and secondary maxima take place respectively in the direction both of the tetragonal and digonal axes, and the minimum in the direction of 55 and 145 degrees from the tetragonal axis. For the perpendicular component, the magnetization vanishes in the direction of the tetragonal, 55 degrees and the digonal axis, and attains a maximum or minimum between them.

(d) In the plane (111), the two components of magnetization vary with a period of 60 degrees. The variation of the magnetization with respect to the orientation of the crystal is exactly similar to the above cases.

Abstracted by Dr. Kotaro Honda.

INFLUENCE OF THE DURATION OF ANNEALING AND VELOCITY OF HEATING UPON THE GRAIN GROWTH IN STEEL. By Kisieleff, A. S. *Anneals* of the Polytechnical Institute of Leningrad, 30, p. 289-315, 1927.

The grain growth was studied in steel, of 0.6 per cent and 1.2 per cent carbon content at temperatures lying between 1830 and 2190 degrees Fahr. (1000 and 1200 degrees Cent.), whereby the dimensions of the grain were measured directly by means of an ocular micrometer. The most pronounced grain growth was observed during the first 3-5 hours of the annealing process, which diminished afterwards and after 30-40 hours the dimensions of the grain approached some limit, which at an annealing temperature 2190 degrees Fahr. (1200 degrees Cent.) was much higher than at 1830 degrees Fahr. (1000 degrees Cent.) The velocity of heating up to the annealing temperature has a singular influence on the grain growth. At fast heating, when the cold sample was introduced into the furnace, which was previously heated up to 2190 degrees Fahr. (1200 degrees Cent.), the grains appeared to be about 10-15 times larger, than at slow heating up to the same temperature. The necessary condition for the grain coarsening consists in a fast passage of the steel through the critical interval. At slow heating up to 1470 degrees Fahr. (800 degrees Cent.) and fast heating from 1470 to 2190 degrees Fahr. (800 to 1200 degrees Cent.) the effect under description does not occur. Again, a heating up to a temperature not lower than 2190 degrees Fahr. (1200 degrees Cent.) is required. At a heating up to 1830 degrees Fahr. (1000 degrees Cent.) the effect does not occur; and at heating up to 2010 degrees Fahr. (1100 degrees Cent.) it takes place only partially.

The author supposes that at an abrupt heating of the steel through the critical range conditions arise in it, which enable the rapid grain growth, whereby these conditions take place only at high temperatures. About the nature of these conditions the author makes only general suppositions, following from the modern conceptions of the grain growth in metals.

Abstracted by M. Oknoff and F. Miller, Leningrad, Russia.

THE EFFECT OF ANNEALING ON THE TENSILE PROPERTIES OF COLD-DRAWN STEEL WIRES. By Tokujirô Matsushita and Kiyoshi Nagasawa. *Kinzoku no Kenkyu*, vol. IV, No. 2, p. 62-69.

With three kinds of cold-drawn carbon steel wires, the change of the tensile properties after annealing at different temperatures below the A_{c1}

point was investigated. It was shown that the curves representing this change are qualitatively the same for all wires irrespective of the carbon content and the reduction ratio.

The increase of the tensile strength and the hardness below 250 degrees Cent. (482 degrees Fahr.) is, according to Professor K. Honda, due to the vanishing of an unstability caused by the cold working by virtue of the temperature agitation, thereby a further slipping becoming somewhat difficult. The decrease of the tensile strength and the hardness in the range 250 degrees Cent. (482 degrees Fahr.) 400 degrees Cent. (752 degrees Fahr.) is due to the plastic yielding of the stress. Above 400 degrees Cent. (752 degrees Fahr.) the rate of decrease becomes markedly less and afterwards again rapid, indicating a temporary increase of these quantities. This abnormal and temporary increase above 400 degrees Cent. (752 degrees Fahr.) is due to the crystal refining caused by the recrystallization.

Abstracted by Dr. Kotaro Honda.

SOME SUGGESTIONS FOR THE CHOICE OF DIE-STEEL. By Dr.-Ing. W. Oertel, Willich. *Maschinenbau*, October 7, 1926, p. 878-880.

The required properties of die-steel are high tensile strength and hardness up to temperatures from 400 to 500 degrees Cent. (752 to 932 degrees Fahr.), high resistance against softening by tempering, great wear resistance and great toughness; further the steel shall not warp or change its volume when heated to working temperature, it should be free from the formation of surface-strains and of hair cracks. Good thermal conductivity of the material is also useful.

For the manufacture of die blocks an unalloyed steel of about 0.60 to 0.70 per cent carbon and 0.60 to 0.80 per cent manganese was used hitherto. For the highest requirements alloy steels are employed. For the improvement of the properties of die steel the addition of nickel-chromium, tungsten, vanadium, silicon and manganese to pure carbon steel are in question. The author gives the physical properties of several steels in the improved state and after tempering to different temperatures from 100 to 700 degrees Cent. (212 to 1292 degrees Fahr.). When working, if a high heating of the die can not be avoided a steel containing 9 to 11 per cent tungsten or 0.30 per cent carbon and 15 per cent chromium would be preferred. This stainless steel possesses a high tensile strength up to a tempering temperature of about 550 degrees Cent. (1022 degrees Fahr.) in addition to a high elongation and reduction of area; further it does not scale up to temperatures of 800 degrees Cent. (1472 degrees Fahr.) and may be easily hardened by cooling in the air from about 1000 degrees Cent. (1832 degrees Fahr.).

Of greatest importance is the knowledge of the wear resistance at working temperature, of the endurance properties and of the resistance against distortion and cracking on repeated change of temperature. This latter property may be studied by the aid of the multiple hardening test. Experience shows us that the resistance against endurance stresses and wearing depends in a high degree upon the amount of its shape change resistance (yield point) and its toughness.

But the life of a die block does not depend only upon the material used,

but also in a high degree upon its treatment and care. The steel must be carefully forged and the coarse casting structure must be replaced by the fine structure of forged steel. The steel must be carefully deoxidized and free from coarse slags and pores. Generally electric steel is to be preferred to open-hearth steel.

After machining, before hardening the die blocks are to be annealed at 600 to 700 degrees Cent. (1112 to 1292 degrees Fahr.) to remove dangerous strains. Overheating while hardening must be avoided. Complicated die blocks must be heated slowly to the hardening temperature and carefully cooled. After hardening, the die blocks should be tempered at a suitable temperature. When working the die blocks are often heated up to 400 to 500 degrees Cent. (752 to 932 degrees Fahr.), from this temperature they must not be carelessly cooled; on the contrary it is advantageous to heat the dies to a uniformly high temperature, determined by the nature of the die steel, by this the life may be increased up to 300 per cent. After longer use hair-cracks are formed on the surface of the die blocks, this being the result of surface strains. The formation of these hair-cracks may possibly be avoided by improving the die blocks before the appearance of the cracks, machining of the die blocks in time is also successful.

Abstracted by Dr. Hans Pollack.

INVESTIGATION OF THE CORROSION OF METALS WITH THE THERMOBALANCE. By Kenzô Inamura. *Kinzoku no Kenkyu*, vol. IV, No. 1, p. 25-32.

The present work was intended to measure continuously the change of metals caused by corrosion. For this purpose a thermobalance was used; the specimen was a commercial iron sheet and the corroding solutions were those of various concentrations of the following seven reagents; water, sodium chloride, sodium carbonate, sodium bicarbonate, sodium nitrate, sodium sulphate and potassium hydroxide. The experiments were carried out at a temperature of 45 degrees Cent. (113 degrees Fahr.) with the following results.

Generally, in these solutions iron is corroded with the formation of flocculent and easily detachable ferric hydroxide and its weight decreases continuously. However, in sodium carbonate and bicarbonate solution a gelatinous corrosion product was formed on the metal surface and could not be detached easily. So the weight of the sample was increased continuously. In acid solutions the continuous measurement could not be made owing to the formation of hydrogen gas bubbles on the metal surface.

Abstracted by Dr. Kotaro Honda.

A THEORETICAL CONSIDERATION OF THE DESULPHURIZING ACTION OF MANGANESE. By Zenichi Shibata. *Kinzoku no Kenkyu*, vol. IV, No. 1, p. 40-43.

In this paper the author has considered the desulphurizing action of manganese during steel refining from the standpoint of theoretical chemistry. The dissociation pressures of MnS and FeS at temperatures from 1000 degrees to 1700 degrees Cent. (1832 to 3092 degrees Fahr.) are calculated by applying Nernst's approximate formula, and the equilibrium constants of the re-

action, $FeS + Mn \rightleftarrows Fe + MnS$, are determined. The degree of the desulphurization is also calculated for ten different percentages of manganese and three temperatures, covering all the ranges to be met with in steel refining furnaces.

Abstracted by Dr. Kotaro Honda.

SCIENTIFIC AND EXPERIMENTAL RESEARCHES ON SPECIAL STEELS. *Revue de Metallurgie*, November, 1925, by F. Sommer and E. Rapatz.

The progress made up to the present, in the manufacture of steel is due in large measure not to previous knowledge, purely scientific, but rather to experience; moreover, the former more or less empirical testing processes have been more and more replaced by scientific methods of working, the industrial purpose of which is essentially to realize more economic manufacture. The economic results of scientific working in works' testing laboratories must be capable of immediate execution, or within a minimum lapse of time, whereas studies in purely scientific institutions are, and must be so generally, more theoretical, and without immediate application, their results not being capable of use for perhaps several years.

The research laboratories in the works have two principal tasks to accomplish; (1) current tests on steel in course of manufacture, and, (2) the study of descriptions of steel already known, and research of new kinds of steel.

Current tests consist of technological experiments permitting of following the steel from the beginning to the finished products, and, likewise, scientific tests of analytical, chemical, and physical nature.

Chemical analysis has been an absolute necessity, for all kinds of steel.

The physical tests, in the first place, consist of determining the characteristics in tensile strength, elongation, reduction of area, elastic limit, proportional limit (with mirror apparatus), modulus of elasticity, and, by way of more and more important extension, resiliency or rebound. These characteristics are of fundamental importance for constructional steels; but, for tool steel, the features obtained by tensile and shock-testing are of no value, inasmuch as the quality of the material depends chiefly upon other properties.

The macroscopic inspections of surfaces etched by various reagents and the use of microscopes on polished and etched specimens have become indispensable for studying the phenomena of solidification, rolling, forging, annealing and improving of the steel, as also for discovering certain defects. However, the users often attach exaggerated importance to the microscope, with the result that observers having had but little practice may easily arrive at wrong conclusions on the quality of the steel.

The thermal study of alterations in structure of special steels is not in current practice, but it has considerable importance for correct research into structural changes in steel of known or new chemical composition.

Research and works laboratories working conjointly is important in that it avoids doing the same work twice; in this connection, it is obviously necessary to take economic conditions into account. In order that purely scientific and theoretical progress may be of use, it is necessary for an intimate union to exist between official research institutes and schools, on the one hand, and the works' testing laboratories on the other hand.

Similarly, the works' laboratories must work in harmony with the works themselves, and never lose sight of the fact that they are working for an economic, and not a merely scientific purpose.

Translated and abstracted—Frederick W. Shaw, Sheffield, England.

ON THE MAGNETIC SUSCEPTIBILITY OF SOME BINARY ALLOYS AT HIGH TEMPERATURES, AND THEIR EQUILIBRIUM DIAGRAMS. By Hikozô Endô. *Kinzoku no Kenkyu*, vol. 3, No. 11, p. 505-526.

The diamagnetic susceptibility of several systems of binary alloys, of which their equilibrium diagrams are already known, was measured both in solid and liquid states by means of Weiss' electro-magnetic method. The present experiment was carried out in order to find the relation between the magnetic susceptibility and the equilibrium diagram in binary alloys, and also to determine whether an intermetallic compound in a binary alloy exists as such in the molten state or in a state decomposed into its component elements, when the compound exists up to the liquidus line. The following relations were confirmed: —

(a) A compound has a magnetic susceptibility characteristic to it. (b) The magnetic susceptibility-concentration curve is a straight line in the case of alloys consisting of a mechanical mixture of two components. (c) In the case of alloys forming a solid solution, the same curve consists of a curve. If a small amount of another element is contained as a solid solution in a strong diamagnetic element such as bismuth or antimony, the magnetic susceptibility of the latter rapidly increases. (d) Intermetallic compounds, which exist up to the liquidus point, are also present undecomposed in the liquid state, though some degree of dissociation is noticeable.

Abstracted by Dr. Kotaro Honda.

DEFECTS AT THE HARDENING OF HIGH SPEED STEEL. By E. Houdremont and H. Kallen, Krefeld. *Zeitschrift des Vereines Deutscher Ingenieure;* February 19, 1927, p. 269 to 70.

The difficulties of high speed steel hardening may be traced to the fact that the hardness of this steel is retained until a temperature close to melting is reached. The authors discuss a particular case of defective hardening.

A commonly used preventive against oxidation is slightly burned charcoal. The tools are put into boxes, which are filled with this charcoal and the boxes are smeared over with clay; herewith the surface of the tool is often carburized and breaks off at quenching, grinding or when working. The authors show some tools in which the carbon content of the surface layer was greater than 1.0 per cent, while the carbon content of the core amounted about 0.66 per cent.

Another phenomenon of the same origin is the formation of little warts and corroded patches on the surface.

To avoid these defects every immediate contact of the tools with the carbon-containing preventive is to be avoided.

Abstracted by Dr. Hans Pollack.

Reviews of Recent Patents

By NELSON LITTELL, Patent Attorney
475 Fifth Ave., New York City—Member of A. S. S. T.

1,651,970, Corrosion-Resisting Alloy, Peirce D. Schenck, of Dayton, Ohio, Assignor to The Duriron Co., Inc., A Corporation of New York.

The principal object of this invention is to provide an alloy having high corrosion resistance, and which, at the same time, may be rolled or cold drawn, and which has a high tensile strength suiting it for a wide variety of uses. The alloy preferably is composed of copper 89 per cent, aluminum 7 per cent, iron 3 per cent and nickel 1 per cent, and due to the qualities enumerated, is suitable for a wide range of service for which the normal acid resisting alloys are unsuited because of their hardness and brittleness. The present alloy may be hot-rolled or cold drawn. It is possible to successfully roll sheets 0.025 inch in thickness from this alloy.

1,652,027, Process for the Manufacture of Very Hard Metallic Alloys, Hugo Lohmann, of Berlin-Johannisthal, Germany.

This patent describes the production of very hard metal alloys, approximating the hardness of a diamond, free from brittleness and therefore suitable for cutting tools and similar purposes. In the hard alloys of the prior art, the hardness of the ferrous metal has varied with the percentage of carbon present and an increase of carbon is accompanied by an increase in brittleness. In nonferrous alloys, the hardness is also usually due to the presence of carbide, and although these alloys may be used without chilling, they are difficult, if not impossible, to forge, roll or press. By the present invention, alloys are produced which, while being very hard, offer a high resistance to breakage and may be forged, rolled or worked in any other manner. The process comprises essentially combining the ingredients of the previous hard alloys with boron and silicon during the melting operation so that the resulting alloy is free from carbon and oxygen and may therefore be worked and the hardness increased by mechanical working. The process of melting the alloy and mixing the various ingredients is described in considerable detail and specific directions are given for carrying out this process.

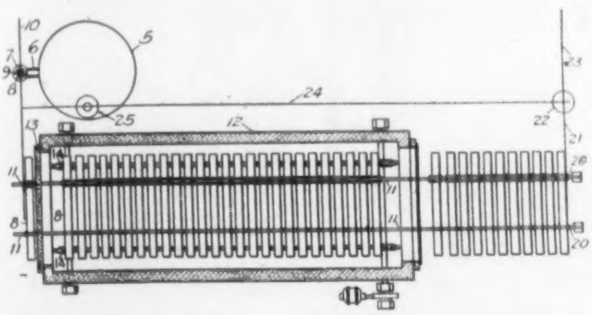
1,651,222, Method of Making Sheets, Otho M. Otte, of Tarentum, Pennsylvania, Assignor, By Mesne Assignments, to Allegheny Steel Co., of Brackenridge, Pennsylvania, A Corporation of Pennsylvania.

This patent describes a method for manufacturing steel or alloy sheets suitable for deep drawing operations to present a high surface finish free from scale. In particular, the invention is usable with stainless iron alloys having a chromium content preferably between 11 and 21 per cent. It consists in applying a protective envelope of nickel or the like by electroplating on the sheet bars after they have been pickled

and rolling the plated bars to the desired thickness after which the nickel or other envelope is removed to present a surface having a high finish free from scale.

1,652,829, **Process of Manufacturing Centrifugally-Cast Cast Iron Pipe and Apparatus Therefor, Arthur Losey, of Jersey City, New Jersey, Assignor to United States Cast Iron Pipe & Foundry Co., of Burlington, New Jersey, A Corporation of New Jersey.**

This patent describes a process and apparatus for the heat treatment of centrifugally-cast cast iron pipes whereby the chilled outer annulus of white iron is annealed and converted into malleable iron by the reactions of heated iron oxide during the annealing operation. The pipes, after casting, are placed in annular malleableizing cells 8 in which the



iron oxides, having been heated in the kiln 5, are released through the spout 6 to pack the space between the walls of the cells 8 and the outer walls of the pipe. The cells 8 and the iron oxide in contact with the outer walls of the centrifugally cast pipe are then moved step by step through the furnace 12 by means of chain dogs 14 in which the heat of the furnace converts the white iron skin of the pipes to malleable iron, by the action of the iron oxide in withdrawing the graphitic carbon from the annulus as it is changed by the heat from combined carbon. Opposite the end of the furnace 12, the malleableized pipes are removed from the cells 8 and the cells return to the kiln 5 for the treatment of other pipes.

1,650,157, **Process for the Elimination of Phosphorus From Pig Iron, Rudolf Schenck, of Munster, Germany, Assignor to Vereinigte Stahlwerke Aktiengesellschaft, Dusseldorf.**

This patent describes a process for eliminating phosphorus from pig iron without previously blowing the pig iron with air which comprises bringing the pig iron into a simultaneous reaction with carbon monoxide and a basic material, such as lime. The process is accomplished technically by blowing the iron admixed with lime or other basic materials with carbon oxide in a converter.

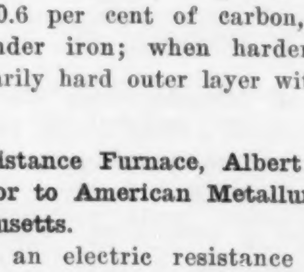
1,649,398, **Steel Alloy, Adolf Fry, of Essen, Germany, Assignor to Fried. Krupp, Aktiengesellschaft, of Essen-on-the-Ruhr, Germany.**

This patent describes and claims a steel alloy having marginal layers

hardened by nitrogenization. The alloy is preferably composed of 0.5 to 2 per cent of aluminum, 0.6 per cent of carbon, 0.5 to 4 per cent of chromium, and the remainder iron; when hardened by nitrogenization this produces an extraordinarily hard outer layer with strength and tenacity in the core zone.

1,652,200, Electric Resistance Furnace, Albert J. Hanson, of **Arlington, Massachusetts, Assignor to American Metallurgical Corp.,** of **Boston, A Corporation of Massachusetts.**

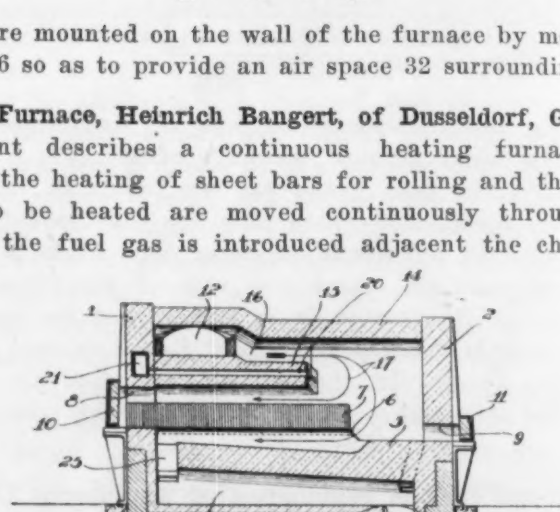
This patent describes an electric resistance furnace in which the resistor ribbons 24 preferably bent into a sinuous shape having bends



21-22 therein are mounted on the wall of the furnace by means of supporting members 26 so as to provide an air space 32 surrounding the resistors.

1,649,648, Furnace, Heinrich Bangert, of Dusseldorf, Germany.

This patent describes a continuous heating furnace, particularly applicable for the heating of sheet bars for rolling and the like, in which the articles to be heated are moved continuously through the furnace and in which the fuel gas is introduced adjacent the charging end and



produces a maximum heating effect adjacent the discharging end, causing the heating effect to progressively increase from the charging to the discharging end. The furnace is provided with end walls 1 and 2, side walls 3 and 4, top 14 and bottom 5, the bottom being provided with the skids 6 for supporting the sheet bars or other blanks to be heated. A charging door is provided at 8 and a discharge opening at 9. Fuel gas inlets are provided at 12 and a muffle wall 15 forms a passage 16 to conduct the burning fuel gas through the furnace in the direction of the

arrow 17. The passage leading to the stack for the discharge of the products of combustion to the air or through a recuperator is indicated at 28.

1,651,638, **Process of Making Steel, Joseph Kent Smith, of Worksop, England, Assignor, by Mesne Assignments, to Granular Iron Co., A Corporation of Michigan.**

This patent describes a process for producing steel from the iron which has been produced from iron-bearing ores without melting of the iron-bearing ores. In accordance with this invention, the iron which has been produced in a solid state without melting is charged into an open-hearth furnace and the charge is covered with a protecting agent, such as pig iron or ferrosilicon, so as to protect the solid produced iron from the oxidizing influence of the furnace atmosphere during the melting and refining operation.

1,640,826, **Electric Furnace, Charles B. Foley, Pottstown, Pa., assignor to Charles B. Foley, Inc., New York, N. Y.**

This electric induction furnace comprises a crucible consisting of a strong inflexible shell having a relatively thin refractory lining and a layer of tubes between the shell and lining for carrying a refrigerant.

1,640,574, **Smelting Furnace, Tannie Lewin, St. Louis, Mo., assignor of one-half to William Lewin, St. Louis, Mo.**

This smelting furnace consists of an elongated cylindrical shell, with closure-heads disposed on the ends of the shell. Rings are fixed circumferentially about the shell adjacent to the ends; fastening members engaging the heads and rings for detachably securing the heads to the shell.

1,643,774, **Electric Furnace, Alvin D. Keene, Pittsburgh, Pa., assignor to Westinghouse Elec. & Mfg. Co.**

A muffle is located in a refractory enclosed furnace chamber, an electric resistor member being supported by the muffle.

1,647,726 **Electric Furnace. Frank T. Cope and Roland F. Benzinger, Salem, Ohio, assignors to The Electric Furnace Company, Salem, Ohio.**

This electric furnace consists of a floor, with piers extended upward from the floor. A hearth comprising a number of plates is mounted upon these piers, and a resistor grid is supported between the piers and intermediate the hearth and floor.

1,649,575, **Externally-Insulated Oven. Emerick B. Crawford, New Haven, Conn., assignor to Oven Equipment & Manufacturing Company, New Haven, Conn.**

This patent describes a protecting metal lining is transversely divided to form lining-units, a linear series of frames being spaced apart to support the adjacent edges of the lining-units. Yielding vapor-tight joints seal the lining-units together and comprise resilient packing and batten-strips and also comprise means for clamping the edges of the units and resilient packing between the frames and battens, whereby the contraction and expansion of any one unit does not effect its neighbor.

THE ENGINEERING INDEX

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Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each month with a specially prepared section of The Engineering Index. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the copy prepared for the annual volume of the Index published by the A. S. M. E.

In the preparation of the Index by the staff of the A. S. M. E. some 1,200 domestic and foreign technical publications received by the Engineering Societies Library (New York) are regularly searched for articles giving the results of the world's most recent engineering and scientific research, thought, and experience. From this wealth of material the A. S. S. T. will be supplied with a selective index to those articles which deal particularly with steel treating and related subjects.

Photostatic copies (white printing on a black background) of any of the articles listed may be secured through the A. S. S. T. The price of each print, up to 11 by 14 inches in size, is 25 cents. Remittances should accompany orders. A separate print is required for each page of the larger periodicals, but whenever possible two pages will be photographed together on the same print. When ordering prints, identify the article by quoting from the Index item: (1) Title of article; (2) name of periodical in which it appeared; (3) volume, number, and date of publication of periodical; and (4) page numbers.

ALLOY STEELS

CASTINGS. The Production and Uses of Ni-Cr-Fe and Co-Cr-Fe Castings, J. F. Kayser. Iron & Steel of Can., vol. 10, no. 12, Dec. 1927, pp. 367-369. Treats of alloys made with Ni, Cr, Fe and Co., and used for high-grade steel as well as stainless or non-corrosive steels; composition of all used in United States and England is given.

MANUFACTURE AND PROPERTIES. The Manufacture and Properties of Alloy Steels, H. C. H. Carpenter. Engineering, vol. 124, nos. 3228 and 3231, Nov. 25 and Dec. 16, 1927, pp. 688 and 785. Review of 4 Cantor lectures delivered at Roy. Soc. of Arts. Nov. 25; States extent of world's production of alloy steels; properties and uses of tungsten, chromium, and manganese steels. Dec. 16: Consideration of nickel, nickel-chromium, and nickel-chromium-molybdenum steels; silicon, chromium-vanadium, tungsten-chromium and tungsten-chromium-vanadium steels.

NITRALLOY. Characteristics of Nitralloy. Am. Mach., vol. 67, no. 23, Dec. 8, 1927, p. 915. Group of special alloy steels that can be surface hardened by subjecting to action of ammonia gas for two to ninety hrs.; superiority of nitriding process. Reference-book sheet.

ALLOYS

ATOMIC GROUPING. Atomic Grouping in Permalloy, L. W. McKeehan. Franklin Inst.—Jl., vol. 204, no. 4, Oct. 1927, pp. 501-524, 2 figs. Deals with problem in local arrangement of atoms in alloy and with what is believed to be new method for solution of such problems. See reprint in Bell Telephone Laboratories, no. B-271, Nov. 1927, 24 pp., 2 figs.

ANALYSIS. Analysis of Stellite, Akrite and Similar Alloys (Zur Analyse der Stellite, Akrite und aehnlich zusammengesetzter Legierungen), E. Deiss. Metall u. Erz, vol. 24, no. 22, Nov. 2, 1927, pp. 537-541. Discusses methods of determining chemical composition of alloys which dissolve in strong acids with great difficulty and, for purposes of analysis, have to be crushed into fine powder, or be decomposed by strong chemicals.

CASTING. Alloys for Casting Under Pressure (Les alliages pour la coulee sous pression). Fonderie Moderne, vol. 21, Dec. 10, 1927, pp. 502-503. Alloys with lead, tin, zinc and aluminum bases; gives physical properties, uses of each and advantages for particular cases; maximum weight possible to cast for each alloy.

CORROSION-RESISTING. Control of Corrosion—New Alloys, W. M. Mitchell. Indus. & Eng. Chem., vol. 19, no. 11, Nov. 1927, pp. 1253-1256. In considering production of new alloys development of any single alloy which is universally corrosion-resistant, or even approximately so, is improbable; most that can be expected is production of various alloys, or groups of alloys, which will have maximum corrosion resistance and hence be serviceable for use with some particular class of corrosive agents; points to be considered in developing new alloys.

ALUMINUM

CASTINGS. The Influence of the Type of Mold on the Mechanical Properties of Cast Aluminum and Its Alloys (Ueber den Einfluss der Formart auf die Materialeigenschaften von gegossenem Aluminium und Aluminium-Gusslegierungen), W. Claus and F. Goederitz. Giesserei Zeitung, vol. 24, no. 18, Sept. 15, 1927, pp. 516-520, 18 figs. Investigations to elucidate influence

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of molding method (chill cast, green sand, dry sand) on mechanical properties, such as grain size, hardness, tensile strength, and elongation; besides pure aluminum there were used American alloy with 8 per cent of copper, and German alloy with 10 per cent of zinc and 2 per cent of copper, microscopical inspection showed that grain size gradually increased from chill cast to dry sand samples. See translated abstract in Foundry Trade Jl., vol. 37, no. 589, Dec. 1, 1927, pp. 159-160, 6 figs.

CENTENARY OF. The Centenary of Aluminum, W. W. Haldane Gee. Engineer, vol. 144, no. 3752, Dec. 9, 1927, pp. 649-650, 3 figs. Discoveries of Humphry Davy; Oersted's experiments; Deville's researches; cryolite; early electrolytic methods.

CORROSION RESISTANCE. Chemical Properties of Pure Aluminum (Propriétés chiques de l'aluminium pur), C. Matignon and J. Calvet. Académie des Sciences—Comptes Rendus, vol. 185, no. 19, Nov. 7, 1927, pp. 909-912. Experimental study of resistance of Hoopes aluminum, which may be 99.8 to 99.98 per cent pure, to corrosion by NaOH and HCL.

CRYSTALS. The Hall Effect in Aluminium Crystals in relation to Crystal Size and Orientation, P. Jones. Lond., Edinburg & Dublin Philosophical Mag., & Jl. of Science, vol. 4, no. 26, Dec. 1927, pp. 1312-1322, 3 figs. Determining whether Hall effect is influenced by dimensions and orientation of crystal aggregates composing metal; experimental results for eight specimens; coefficient independent of crystal size and of orientation of lattice planes in crystal with respect to primary current; absolute value of Hall coefficient for aluminium.

OVERHEAD ELECTRIC LINES. Overhead Transmission Lines of Aluminum (Neue Wege im Freileitungsbau), von Seereider and M. Bosshard. Zeit. für Metallkunde, vol. 19, no. 11, Nov. 1927, pp. 459-470, 47 figs. Discusses use of aluminum and aluminum alloys for transmission; properties of aluminum alloys containing iron, silicon, iron and silicon, titanium, copper, magnesium, magnesium and silicon, copper and magnesium, zinc; effect of heat treatment, heat effect of electric current and its influences on properties of metal.

ALUMINUM ALLOYS

CINDAL. A New Aluminum Alloy, D. R. Tullis. Metal Industry (Lond.), vol. 31, no. 21, Nov. 25, 1927, pp. 487-490, 7 figs. Cindal is primarily intended as corrosion-resisting type alloy, but at same time possesses many new features whch have not hitherto been applied to aluminum alloys; sea-water test results; subsequent treatment of test strips; influences which intensify corrosion; comparative results of degasified and undegasified alloys; effect of degasifying on microstructure.

IRON ESTIMATION IN. The Estimation of Iron in Aluminium Alloys, H. H. Shepherd. Foundry Trade Jl., vol. 37, no. 587, Nov. 17, 1927, p. 128. Reagents required; standardization; method of estimation.

NEW. New Aluminum Alloys at the Materials Show, Berlin, 1927 (Neue aluminiumlegierungen auf der Berliner Werkstofftagung), M. v. Schwarz and K. L. Meissner. Zeit. für die Gesamte Giessereipraxis (Metall Section), vol. 48, no. 47, Nov. 20, 1927, p. 193. Sand cast aluminum, alloys of high elastic limit, silicon-aluminum alloys, also duralumin, alneon and similar plastic alloys.

STRENGTH, TENSILE. Influence of Casting on the Strength of Aluminum and Magnesium Alloys (Zwangsläufige Einflüsse des Giessvorganges auf die Festigkeitseigenschaften von Aluminium-und Magnesiumlegierungen und ihre Bedeutung für den Konstrukteur), G. Schreiber. Zeit. für Metallkunde, vol. 19, no. 11, Nov. 1927, pp. 456-458, 10 figs. Statistical, frequency curve study of tensile strength and elongation of electron metal, various aluminum alloys and of steel and iron castings.

ZINC ESTIMATION IN. The Volumetric Estimation of Zinc in Aluminium Alloys, H. H. Shepherd. Foundry Trade Jl., vol. 37, no. 590, Dec. 8, 1927, pp. 175-176. When percentage of zinc in any of these alloys exceeds 2 per cent, determination of amount should be carried out by volumetric or potassium ferrocyanide method; solutions required.

ALUMINUM BRONZE

LARGE INGOTS, MAKING. Making Large Bronze Ingots, J. Strauss. Iron Age, vol. 120, no. 23, Dec. 8, 1927, pp. 1577-1581, 8 figs. Difficulties overcome in pouring and machining aluminum bronze; refinements necessary in heat treating and forging.

PROPERTIES. Aluminum Bronze, R. C. Reader. Foundry Trade Jl., vol. 37, no. 588, Nov. 24, 1927, p. 143. Deals with general properties; bronze; its tensile strength and elongation and further useful properties; aluminum bronze golf clubs.

AXLES

FATIGUE CRACKS IN. A Study of Fatigue Cracks in Axles, H. F. Moore. Forging—Stamping—Heat Treating, vol. 13, no. 11, Nov. 1927, pp. 447-449. Axles which had been in service were subjected to special test devised to indicate presence of cracks before rupture was complete; method of testing. Abstracts from Bul. No. 165, Eng. Experiment Station, Univ. of Ill.

BERYLLIUM

THERMAL EXPANSION. Thermal Expansion of Beryllium and Aluminum Beryllium Alloys, P. Hidnert and W. T. Sweeney. U. S. Bur. Standards—Sci. papers, no. 565, Oct. 29, 1927, pp. 533-545, 10 figs. Results on linear thermal expansion of beryllium (98.9 per cent.) and five aluminum-beryllium alloys containing various percentages of beryllium (4 to 33 per cent); beryllium expands considerably less than other elements of sub-group LIB (magnesium, zinc, cadmium, and mercury); coefficients of expansion of aluminum-beryllium alloys decrease with increase in beryllium content.

BLAST FURNACES

COKE-ASH ANALYSIS. The Effect of Varying Ash in the Coke on Blast-Furnace Working, C. S. Gill. Iron & Steel of Can., vol. 10, no. 12, Dec. 1927, pp. 374-376, 2 figs. Gives quantities of ash found in coke used in blast furnace operation and sulphur in pig iron and analyzes effect of ash on pig obtained, from furnace 55 ft. high, 18 ft. diameter.

HEAT DIAGRAM. A New Blast-Furnace

Heat Diagram, P. Reichardt. Iron & Coal Trades Rev., vol. 115, no. 3116, Nov. 18, 1927, p. 753. Author suggests diagram in which heat requirements in different zones of temperature in blast furnace are compared with heat available within those zones. Translated from Archiv für das Eisenhüttenwesen.

HOT-BLAST STOVES. Improving Hot-Blast Stove Efficiencies, J. B. Fortune. Iron & Coal Trades Rev., vol. 115, no. 3119, Dec. 9, 1927, pp. 857-859, 5 figs. Results that have been obtained at Margam Iron and Steel Works of Baldwins, Ltd., Port Talbot, England, in endeavor to reduce amount of gas used in heating blast.

BRASS

ANNEALING. Critical Temperatures in the Annealing of Brass Wire (Kritische Temperaturen beim Glühen von Messingdraht), F. Ostermann. Zeit. für Metallkunde, vol. 19, no. 9, Sept. 1927, pp. 349-351, 12 figs. Both tensile strength and ductility are considerably reduced and metal tends to become brittle; this phenomenon is especially marked after double annealing at 650 deg.; most satisfactory structure of brass containing 63 per cent. Cu is obtained by annealing at 600 deg. and cooling slowly or by annealing at 700 deg. and quenching; in any case a second annealing operation should be avoided.

HIGH-GRADE. High Grade Brass (Qualitätsmessing), J. H. Wieland. Zeit. für Metallkunde, vol. 19, no. 11, Nov. 1927, pp. 417-422. Discusses manifold specification requirements and ways of satisfying them; brass alloys, phase rule diagrams, chemical and mechanical properties; melting, casting, rolling, pressing, drawing and heat treatment, initial strains, effect of impurities, prospects.

INTERNAL STRESSES. Detection of Internal Stress in (Brass) Rods and Tubes (Der Nachweis innerer Spannungen in Stangen und Rohren), G. Sachs. Zeit. für Metallkunde, vol. 19, no. 9, Sept. 1927, pp. 352-357, 8 figs. Method depends on changes of shape undergone by specimen when small layer is trimmed off outside; mathematical expression is deduced from theoretical considerations connecting these changes with internal stress in metal.

NAVAL, SPECIFICATIONS. Naval Brass (Admiralty Mixture) Bars and Sections. Brit. Eng. Standards Assn., no. 251, July 1927, 13 pp., 8 figs. Definition of bars and sections; ruling thickness; quality of material; methods of manufacture; freedom from defects; margins of manufacture; tests.

NAVAL, SPECIFICATIONS. Naval Brass (Special Mixture) Bars and Sections. Brit. Eng. Standards Assn., no. 252, July 1927, 13 pp., 8 figs. Definition of bars and sections and ruling thickness; specifications for quality of material, methods of manufacture; freedom defects, margins of manufacture, provision of test pieces, mechanical tests, etc.

SHEET, TESTING. Physical Properties and Methods of Test For Sheet Brass, H. N. Van Deusen, L. I. Shaw and C. H. Davis. Bell Telephone Laboratories—Reprint, no. B.-269, Oct. 1927. 37 pp., 20 figs. Investigation of various thicknesses, grades, and tempers of brass sheet and development of simple and reliable methods of test thin-sheet metals.

BRASS FOUNDRIES

HEALTH HAZARDS. Health Hazards of Brass Foundries. Iron Age, vol. 120, no. 23, Dec. 8, 1927, p. 1601. Ague or oxide chills more intense in buildings closed against winter weather; due to zinc oxide from open ladles; employees in 22 brass foundries were examined. Abstracted from Public Health Bulletin no. 157.

PRACTICE. The Fundamentals of Brass Foundry Practice, R. R. Clarke. Metal Industry (N. Y.), vol. 24, nos. 7, 8, 9, 10, and 11, July, Aug., Sept., Oct., and Nov. 1926, pp. 283-284, 318-320, 365-366, 417-418, and 453-454, and vol. 25, nos. 1, 2, 3, 4, 5, 8, 9, 11, and 12, Jan., Feb., Mar., Apr., May, July, Aug., Sept., Nov., and Dec., 1927, pp. 6, 63-64, 105-106, 146-148, 194-195, 327, 369-370, 455-456, and 493-494, 51 figs. Description of basic laws which control melting and casting of metals and their application to practical foundry operations.

BRONZES

ANTIQUE, METALLURGY OF. Metallurgy of Antique Bronzes (Contribution à la metallurgie des bronzes antiques), D. Buttescu. Annales des Mines de Roumanie, vol. 10, no. 9-10, Sept.-Oct. 1927, pp. 459-464, 15 figs. Chemical analyses and metallography of ancient Egyptian, Japanese, Greek, Roman and other bronzes.

CASTING. The Essentials of Bronze Casting, G. K. Geerlings. Brass World, vol. 23, no. 11, Nov. 1927, pp. 367-371 and 377, 12 figs. Describes sand-core and "lost wax" processes; cast bronze, as compared to rolled, drawn and extruded bronze, varies in color and is bound to appear differently; if finesse and color are important to architect he should not use cast bronze with others; among early architectural usages of bronze it was not cast but applied to wood surface; this is particularly true in doors.

FOUNDING. Developments in Engineering Bronze Founding. Metal Industry (Lond.), vol. 31, no. 22, Dec. 2, 1927, pp. 511-512. Progress in bronze castings; tilting furnaces; electric furnace for foundry work; gas absorption in bronze; grain size and strength; worm-wheel blanks; tin and tin substitutes. Paper read before joint meetings of Inst. of Metals & Inst. of Brit. Foundrymen. See also Foundry Trade Jl., vol. 37, no. 591, Dec. 15, 1927, pp. 195-198, 2 figs.

CASE-HARDENING

NITRATION HARDENING. Nitralloy and the Nitriding Process, H. A. DeFries. Machy. (N. Y.), vol. 34, no. 5, Jan. 1928, pp. 358-359. Special alloy steels which can be surface hardened by being subjected to action of ammonia gas for from two to ninety hours, while material is heated to 875 deg. Fahr. without subsequent quenching; standard electric furnaces easily adaptable; composition, properties and uses; heat treatment previous to nitriding; nitridng process and equipment; depth and hardness of case.

NITRATION HARDENING. Surface Hardening by Nitrogen, Foundry Trade Jl., vol. 37, no. 588, Nov. 24, 1927, pp. 135-136. New process of Dr. Fry, of Research Laboratories of F. Krupp of Essen consist of sub-

jecting parts to be hardened to action of ammonia gas at temperature of approximately 500 deg. Cent. for period of time varying from 40 to 120 hr.; ammonia is dissociated, and portion of nitrogen thus formed passes into solid solution in outer layers of parts; one of most valuable features of process is small amount of distortion which parts undergo during nitrogen treatment; electric furnaces essential.

PRINCIPLES. Facts and Principles Concerning Steel and Heat Treatment, H. B. Knowlton. Am. Soc. for Steel Treat.—Trans., vol. 13, no. 1, Jan. 1928, pp. 142-154. Explains what case-hardening is, reviews history; reasons for case-hardening; selection of steels; S. A. E. specifications for plain carbon case-hardening steels; presents table giving chemical composition of alloy steels commonly used for case-hardening.

SOFT STEEL. Case-Hardening of Soft Steel, G. A. Nelson. West Mach. World, vol. 18, no. 11, Nov. 1927, pp. 532-533, 7 figs. Operations in heat treatment department of Pacific Gear & Tool Works; results obtained with soft steel heat treated in electric furnace.

CAST IRON

CARBONIZATION RETORTS, FOR. The Use of Cast Iron for Retorts for Low Temperature Carbonization. Foundry Trade Jl., vol. 37, no. 590, Dec. 8, 1927, p. 176. Strong claims are now being made on behalf of cold-blast pig iron; this is being used in constructing retort for one of lastest processes and it is maintained that well-known dense and tough character of cold-blast iron will overcome difficulties, especially since there is no objection in way of actual casting.

FATIGUE. Fatigue of Cast Iron, C. H. Bulleid and A. R. Almond. Engineering, vol. 124, no. 3232, Dec. 23, 1927, p. 827, 6 figs. Data on an iron suitable for light castings and typical cylinder iron; from results of these two irons and those obtained previously, it appears that ratio of fatigue stress to transverse stress varies greatly in different irons, and may be very low.

HARDNESS. Hardness and Machinability of Cast Iron, W. Melle. Foundry Trade Jl., vol. 37, no. 591, Dec. 15, 1927, p. 201, 3 figs. Investigations to find out relationship between these two mechanical properties; experiments were made with various kinds of cast irons, Brinell hardnesses of which were within range from 90 to 240 kg. per sq. mm., and show that it is quite possible to examine machinability of cast iron by Brinell test, but relationship between these two properties is not linear one. Translated from Giesserei-Zeitung, 1927, no. 17, pp. 485-486.

MAURER DIAGRAM. The Maurer Diagram of Cast Iron at Different Cooling Velocities (Das Gusseisendiagramm von Maurer bei verschiedenen Abkühlungsgeschwindigkeiten), E. Maurer and P. Holtzhaussen. Stahl u. Eisen, vol. 47, no. 43, Oct. 27, 1927, pp. 1805-1812, 21 figs. partly on supp. plates. Results of tests carried out in iron foundry of Fried. Krupp, Grusonwerk, Magdeburg-Buckau; Maurer diagram with normal cooling velocity and when casting in preheated molds and ingots; effect of cooling velocity on structure formation and mechanical properties.

PHOSPHORUS, INFLUENCE OF. Effect of Phosphorus on Mechanical Properties of Metals, S. S. Nekrity. Vestnik Metallopromishlennosty, no. 9, Sept. 1927, pp. 35-42. Original experimental study showing beneficial effect of phosphorus on strength and endurance of malleable cast iron; author believes phosphorus will be regarded as desirable component. (In Russian)

SILICA ADDITION. Addition of Silica to Castings (Addition du silicium dans la fonte), M. Debar. Fonderie Moderne, vol. 21, Nov. 25, 1927, pp. 472-476, 1 fig. Action and advantages of silica in semi steel mixtures and gray iron castings; shows how difficulties encountered were due to manner of adding ferrosilica.

TESTING. Tests of the Fatigue Strength of Cast Iron. Railroad Herald, vol. 31, no. 11, Oct. 1927, pp. 35-37, 2 figs. Castings from foundry of Allis-Chalmers tested for impact, fatigue and static strength. From Bul. No. 164 of Eng. Experiment station of Univ. of Ill.

WELDING. Welding of Gray Cast Iron. Modern Min., vol. 4, no. 12, Dec. 1927, pp. 315-318, 10 figs. How properties affect welding procedure; preheating; welding; annealing; testing.

CASTING

AUTOMOBILE CYLINDERS. Foundry Trade Jl., vol. 37, no. 586, Nov. 10, 1927, pp. 103-104. Discussion of paper by W. West on subject of engine cylinder castings as illustration of progress which has been made in use of oil sand.

CASTINGS

BRONZE AND BRASS GEAR. Bronze and Brass Castings for Gears. Machy. (N. Y.), vol. 34, no. 5, Jan. 1928, p. 390. Recommended practice approved by American Gear Manufacturers' Assn.; use and chemical composition; chemical analysis; sampling; inspection; rejection.

CHROMIUM

PROPERTIES AND USES. Chromium, J. W. Furness. Metallurgist (Supp. to Engineer), Nov. 25, 1927, p. 174. Review of information on properties and uses of chromium and on production and consumption of metal.

COBALT

DETERMINATION IN COMMERCIAL METALS. Determination of Cobalt and Other Alloyed Elements in Cobalt Metal, Cobalt Steel, and High-Speed Tool Alloys (Die Bestimmung des Kobalts und der Nebenbestandteile in Kobaltmetall und Kobaltstählen sowie in Hartschneidmetallen), E. Schiffer. Stahl u. Eisen, vol. 47, no. 38, Sept. 22, 1927, pp. 1569-1571 and discussion 1571-1572. Determination of cobalt in commercial metal is most satisfactorily effected by electrolysis in usual way after removing heavy metals and iron; cobalt steel with low content of cobalt is dissolved in hydrochloric acid with help of oxidizing agent; for separation of iron from cobalt in high-cobalt steel either process is most satisfactory. See brief translated abstract in Chemistry & Industry, vol. 46, no. 45, Nov. 11, 1927, p. 845.

COKE

BLAST-FURNACE. The Effect of Varying Ash in the Coke on Blast-Furnace Working, C. S. Gill. Gas Engr., vol. 43, no. 619, Nov. 1927, pp. 288-289, 1 fig. General requirements of good blast furnace coke; effect of fluctuating and consistent ash.

COMBUSTION

CONTROL. Combustion Control for Industrial Furnaces, J. Ryan. Iron & Steel Engr., vol. 4, no. 12, Dec. 1927, pp. 493-498, 9 figs. Treats of advantages of automatic control from both fuel and product standpoint in gas and oil-fired furnaces; control valve governs by-pass, main flow and speed of heating; cites various industries using automatic furnace control.

COPPER

RIM NOTCHES IN. Rim Notches in Copper Plate Cylinders (Die Entstehung von unebenen Rändern an Holkörpern aus Kupferblech), K. Kaiser. Zeit. für Metallkunde, vol. 19, no. 11, Nov. 1927, pp. 435-437, 8 figs. Formation of rim notches is due to non-isotropy of material; can be prevented by proper heat treatment and rolling; relation between orientation of crystallites and rim notching; extraordinary importance of last intermediate heating.

COPPER ALLOYS

COPPER-ZINC. Composition of Copper-Zinc Alloys (Der Aufbau der Kupfer-Zinklegierungen), O. Bauer and M. Hansen. Zeit. für Metallkunde, vol. 19, no. 11, Nov. 1927, pp. 423-434, 26 figs. Experimental phase-rule and crystallographic study, done at Kaiser Wilhelm Institut for Metallurgical Reasearch.

HEAT TREATMENT. The Effect of Heat Treatment on Some Mechanical Properties of 88: 10: 2 Copper-Tin-Zinc Alloy, R. J. Anderson. Am. Metal Market, vol. 34, no. 243, Dec. 17, 1927, pp. 4-7, 23 figs. Experimental data. Bibliography.

RESISTIVITY. The Temperature-Electrical Resistivity Relationship in certain Copper Alpha Solid Solution Alloys, A. L. Norbury. Lond., Edinburgh & Dublin Philosophical Mag., & Jl., of Science, vol. 4, no. 26, Dec. 1927, pp. 1338-1341, 2 figs. Alloys used in form of annealed wires of 0.03 in. diam.; experimental methods; results obtained collected in table; resistiviy against temperature plotted to give linear relationship between 191 and 438 deg. Cent. for all alloys except manganese-copper and nickel-copper alloys.

COPPER INDUSTRY

PRODUCTION, MARKET, AND OUTLOOK. Copper Production, Market and Outlook, J. D. MacKenzie. Min. & Met., vol. 8, no. 252, Dec. 1927, pp. 497-499, 1 fig. Consumption of copper increases 60 per cent each decade; capacity to produce now exceeds demand; scrap recovery over one-quarter of new production.

CORROSION

PROBLEMS. The Practical Problems of Corrosion, U. R. Evans. Chem. & Industry, vol. 46, nos. 34 and 36, Aug. 26 and Sept. 9, 1927, pp. 347t-355t and 363t-372t, 17 figs. Aug. 26: Critical examination of the use of inhibitive chemicals. Sept. 9: Study of protective coatings.

REFRIGERATING INDUSTRY

REFRIGERATING INDUSTRY. Corrosion in the Refrigerating Industry, J. K. Roberts, H. O. Forrest, and R. P. Russell. Refrig. Eng., vol. 14, and no. 6, Dec. 1927, pp. 173-182 and 187, 17 figs. A. S. R. E. corrosion committee presents draft of its final report; corrosion of iron, steel and galvanized steel in brine systems may be greatly reduced by addition of sodium dichromate to brine; disodium phosphate as corrosion retarder; comparison of dichromate and phosphate treatments; other materials as retarders in brine; corrosion in condenser systems; corrosion in salt water; heat-transfer measurements for paint coatings and rust films; recommendations for treatments and instructions for application.

TESTING. Corrosion, G. D. Bengough. Metal Industry (Lond.), vol. 31, no. 23, Dec. 9, 1927, pp. 533-534. Method of measuring corrosion; results show that actual conditions of service must first of all decide tests required; then main factors must be obtained.

CRYSTALS

BRASS, TENSION AND COMPRESSION. Tension and Compression Effects on Brass Crystals (Zug-Druckversuche an Messingkristallen), G. Sachs and H. Shoji. Zeit. fuer Physik, vol. 45, no. 11-12, Nov. 1927, pp. 776-796, 24 figs. Elaborate investigation of Bauschinger effect; elimination of asymmetry by annealing; preparation of brass crystalls; maximum limit of Bauschinger effect; deformations not causing changes in density.

DEFORMATION AND HARDENING. Deformation, Rupture, and Hardening of Crystals, M. Polanyi, Metal Industry (Lond.), vol. 31, no. 22, Dec. 2, 1927, pp. 506-507 and 518. Deals mainly with investigations of metallic crystals; monocrystalline wires and rods; slip in single crystals; effect of cold working on slip. Abstract of paper read at Faraday Soc.

CUPOLAS

CHARGING. The Ruscoe Cupola Charger Foundry Trade Jl., vol. 37, no. 587, Nov. 17, 1927, p. 117. Automatic feeding machine can be attached to existing plants, and renders installation of hoist unnecessary.

FLUORSPAR IN. The Use of Fluorspar in Cupola Melting (Die Verwendung von Flusspat beim Kupolofenschmelzen), Osann. Giesserei, vol. 24, no. 23, Dec. 1, 1927, pp. 659-664, 2 figs. Discusses possible uses of fluorspar; influence of consistency of slag; desulphurizing effect; limestone and fluorspar; economic considerations.

PRACTICE. Hints on Cupola Practice, A. Sutcliffe. Foundry Trade Jl., vol. 37, no. 588, Nov. 24, 1927, p. 146. Principal causes of bad melting are faulty quantity and faulty delivery of blast, associated with poor arrangement of charge in furnace; author is of opinion that where adjustments are required in quantity of iron which founder requires to be delivered to him at commencement of his casting operations, they cannot be made satisfactorily by alterations of blast or of weight and disposition of

charges in one cupola except within inconsiderable limits; ascertaining blast requirements; numerous large tuyers advocated.

PULVERIZED-COAL SUPPLEMENTARY FIRING. The Influence of Pulverized-Coal Supplementary Firing on Melting Process in Foundry Cupolas (Der Einfluss der Kohlenstaubzusatzfeuerung auf den Schmelzvorgang im Giessereikuppelofen), F. Körber. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Duesseldorf, vol. 9, no. 16, 1927, pp. 247-264, 3 figs. Nature of pulverized-coal firing and its use as supplementary firing in shaft furnaces; effect of this firing method on furnace process; results of tests; comparison with supplementary oil firing for cupolas.

DIE CASTING

ALLOYS. Die-Casting Alloys. Machy. (Lond.), vol. 31, no. 793, Dec. 22, 1927, pp. 397-398. Alloys can be conveniently divided into three groups, namely, those of low melting point, which include tin-base, lead-base, and zinc-base alloys; aluminum-base alloys; and copper-base alloys, which includes 60/40 brass, aluminum bronze, high-tensile brass, and aluminum-brass each of which is discussed.

PRESSURE. Die Casting under Pressure (Le moulage en coquille sous pression), P. Schimpke. Fonderie Moderne, vol. 21, Nov. 25, 1927, pp. 467-471, 6 figs. Treats of die casting various alloys in steel molds; methods of injection of molten metal into molds; hand and automatic molding machines, using compressed air for pressure on metal during casting.

EDUCATION, INDUSTRIAL

METALLURGISTS. Training Metallurgists, H. B. Dirks. Iron Age, vol. 120, no. 26, Dec. 29, 1927, 3 figs. New course designed to fill gap not occupied by previous curricula; four-year and five-year men.

PROCESS. Die-Casting Process (Das Spritzgussverfahren), P. Schimpke. Stahl u. Eisen, vol. 47, no. 26, June 30, 1927, pp. 1069-1075, 7 figs. Reviews field of production of die castings under pressure, or "squirt castings," dealing with characteristics of process, alloys employed, casting and solidification procedure, molds, casting machines, etc.; characteristics of process are described as forcing or squirting of molten metals by means of piston or plunger, and cylinder, or by compressed gas into an accurately shaped permanent mold usually of steel or cast iron; clean, accurately dimensioned casting, superior in dimensional accuracy to gravity casting, is thus obtained, which needs little or no machining; properties desirable in metals for die casting; characteristics of entry or streaming of molten metal into mold are of great importance. See also translated abstract in Metallurgist (Supp. to Engineer), Nov. 25, 1927, pp. 169-172.

ELECTRIC FURNACES

CIRCUIT CALCULATION. The Calculation of Electric Furnace Circuits, R. Catani. Am. Electrochem. Soc.—advance paper, no. 8, for mtg. Sept. 22, 1927, 129-156, 7 figs. In first part furnaces with one circuit only are considered: (1) apparent maximum power (2) maximum absorbed power (3) resistances: lead resistance, electrode and arc resistance; (4) reactances, (5) efficiency: formulas, efficiency and power (6) calculations from efficiency and from voltage. In second part furnaces with several circuits are discussed: (1) mutual induction (2) correct disposition of circuits.

HEAT-TREATING. Economies of Electric and Fuel Furnaces, C. L. Ipsen and A. N. Otis. Forging—Stamping—Heat Treating, vol. 13, no. 11, Nov. 1927, pp. 439-442, 4 figs. Indicates factors effecting efficiency of furnaces, and describes installations where electric heat has proved to be advantageous.

HIGH-FREQUENCY INDUCTION. High-Frequency Induction Furnaces (Zur Metallurgie des Hochfrequenc-Induktionsofens), F. Wever and G. Hindrichs. Archiv für das Eisenhüttenwesen, vol. 1, no. 5, Nov. 1927, pp. 345-352 and (discussion) 352-355, 18 figs. Refining and deoxidizing on acid hearth; production of different steels and alloys steels; tests with 100-kw. high-frequency furnace.

HIGH-FREQUENCY INDUCTION. High-Frequency Induction Furnaces for Small Charges (Hoch-frequenzöfen für Kleine Einsätze), A. Kussmann. Zeit. für Metallkunde, vol. 19, no. 9, Sept. 1927, pp. 346-348, 2 figs. Current supply for small (5 kw-hr.) induction furnace is obtained by transforming up ordinary a. c. supply to 6000 volts by means of suitable transformer in primary circuit of which is arranged ammeter, choking coil, and cut-out switch; high-tension current thus obtained is shunted through three oil condensers in parallel, and converted to high frequency by means of spark-gap device. See brief translated abstract in Chem. & Industry, vol. 46, no. 45, Nov. 11, 1927, p. 848.

INDUCTION. The Actual State of the Induction Furnace (L'état actuel du four à induction), P. Bunet. Chimie & Industrie, vol. 18, no. 5, Nov. 1927, pp. 751-757, 9 figs. Treats of induction furnaces and transformers; touches on Schneider type; furnaces without iron and suggests possible improvements; high frequency furnaces also noted with comments on their disadvantages.

MELTING. High Frequency Induction Melting. Colliery Guardian, vol. 135, no. 3493, Dec. 9, 1927, pp. 1432-1433, 1 fig. Recent development is motor-generator type of Ajax-Northrup furnace; demonstration plant at Bilston has been used for melting steel, brass, copper, pure nickel, nickel-silver, aluminum and other metals and alloys.

MELTING. High-Frequency Induction Melting, D. F. Campbell. Iron & Steel of Can., vol. 10, no. 12, Dec. 1927, pp. 363-366, 5 figs. Furnace used in Sheffeld Steel Works for melting lots of 400 to 500 lb. of steel; 18 per cent tungsten steel in 300 lb. lots can be melted in 45 min.; very low-carbon alloys can easily be made; 150-kva. generator used.

MIGUET. The New Miguet Elecric Furnace With Continuous Electrode (Le nouveau four électrique Miguet à électrode continue), R. Sevin. Jl. du Four Electrique, vol. 36, no. 16, Nov. 15, 1927, pp. 245-247, 5 figs. Furnace installed at Montricher; method of operating it; advantages of this type of furnace and economy in its use.

NON-FERROUS METALS. Electric Melting Furnaces for Non-Ferrous Metals (Elektro-

schmelzöfen für Nichteisenmetalle), H. Nathusius. Giesserei-Zeitung, vol. 24, no. 22, Nov. 15, 1927, pp. 630-635. Points to greater progress made in America in use of electric furnaces for this purpose; advantages of electric over fuel-fired furnaces; descriptions of different types and examples of melting costs and economy.

REGULATORS. Automatic Electrode Regulating Devices for Electro-Steel Furnaces, S. Schey. AEG Progress, vol. 3, no. 11, Nov. 1927, pp. 358-362, 7 figs. Regulation by two means; separately excited, d.c. motors employed as electrode lifting motors, controlled by regulation of armature voltage; and electro-hydraulic regulation.

ELECTRIC WELDING

SINGLE-OPERATOR MACHINE. General Electric Single-Operator Type Welder. Am. Mach., vol. 67, no. 26, Dec. 29, 1927, pp. 1039-1040, 1 fig. Machine includes four-bearing, ball-bearing motor-generator set with flexible coupling generator rated at 300 amperes, one hour, 50 deg. Cent., and driving motor at 15 hp., 40 deg. Cent., continuous rating; field control unnecessary; meters have metal front except for glass over scale; for stationary or portable use.

ELECTRIC WELDING, ARC

HYDROGEN. Recent Developments in Welding, S. Vaughan. Foundry Trade Jl., vol. 37, no. 589, Dec. 1, 1927, p. 156. Welding vs. castings; hydrogen-enveloped metallic arc; use of atomic hydrogen.

MACHINES. Motor Driven Arc Welder. Boiler Maker, vol. 22, no. 12, Dec. 1927, p. 338, 1 fig. Most recent addition to Fuzon line of arc welders is d.c. machine operated by 3-phase, a.c. motor, either 220 or 440 volts supply.

MANUFACTURING WELDED PARTS. Manufacturing Welded Parts, H. Levine. Iron Trade Rev., vol. 81, no. 25, Dec. 22, 1927, p. 1549. Points to need of establishments for manufacturing welded steel products; steel "weldery" which he advocates, would be producer of welded articles just as foundries, pressed metal plants and forge shops are producers of castings, stampings and forgings.

OIL-CRACKING VESSELS. Welding Oil Pressure Cracking Vessel, R. Stresau. Nat. Petroleum News, vol. 19, no. 47, Nov. 23, 1927, pp. 64-71, 18 figs. Type of design required for stills operating at 900 deg. Fahr. and pressures of 1000 lb. per sq. in. or more must also be such that material used in every part of vessel is equally stressed; process developed by A. O. Smith Corp. in manufacturing pressure stills.

RAILS. Building Up Battered Rail Joints by Electric Arc Welding. Ry. Eng. & Maintenance, vol. 23, no. 12, Dec. 1927, pp. 522-524. Electric method has been confined to western states; outfits placed in regular service in 1924, first on Western Pacific and later on other western roads consists of gas engine and generator mounted on track car, with necessary conductor cables and grinders; welding unit consists of 40-hp. 4-cylinder gas engine direct-connected through clutch to 250-ampere welding generator.

ELECTRIC WELDING, RESISTANCE

SHEET-METAL FABRICATION. Fabricating Sheet Metal Products by Use of Multiple Welding, W. T. Ober. Iron Trade Rev., vol. 81, no. 26, Dec. 29, 1927, pp. 1601-1602. Development of machine for performing several spot welds in one operation speeds up production; large flat electrodes overcome non-uniformity resulting from uneven wear of pointed electrodes.

TANK. Seam Welding Oil Containers. Welding Engr., vol. 12, no. 11, Nov. 1927, pp. 33-36, 3 figs. Economical production of high grade tanks secured through carefully arranged use of several welding processes in combination.

FERROSILICON

SILICON DETERMINATION. Rapid Determination of the Silicon Content of Ferrosilicon by Means of the Density (Schnellbestimmung des Siliciumgehaltes von Ferrosilicium durch Dichtebestimmung), M. Schwarz, Chemiker-Zeitung, vol. 51, no. 84, Oct. 22, 1927, p. 815. Curve is given showing relation between density of ferrosilicon at room temperature and its content of silicon; in absence of impurities or of pores in material, silicon content can be determined with accuracy of 1 per cent.

FORGING

OPERATIONS AND EQUIPMENT. Forging, W. M. Hepburn. Am. Gas Jl., vol. 127, no. 9, Nov. 1927, pp. 56-58, 8 figs. Deals with forging which applies to steel; forging press; hammer forging; continuous and rod-end forges; operating costs.

FORGING MACHINES

DIES. Forging Machine Dies, W. S. Dewell. Machy. (Lond.), vol. 30, no. 761, 764, 773 and 781, May 12, June 2, Aug. 4 and Sept. 29, 1927, pp. 176-178, 262-263, 556-557 and 817-819, 8 figs. Data relating to long upset, using ¾-in. diameter metal. June 2: Three-arm clutch shaft. Sept. 20: Action of heading tools; results of uneven heating.

FORGINGS

BRASS. Manufacturing Brass Forgings in Michigan Plant, E. Bremer. Iron Trade Rev., vol. 81, no. 26, Dec. 29, 1927, pp. 1597-1600, 6 figs. Experience of Mueller Co. during war period proves invaluable in developing production of numerous forged brass articles for peace-time consumption; brass forgings are produced by squeezing hot blank between two closed or partly closed dies.

HEATING AND HANDLING. Furnace Aids in Modernizing Forgings, F. W. Manker. Forging—Stamping—Heat Treating, vol. 13, no. 11, Nov. 1927, pp. 431-432, 2 figs. Equipment used for heating and handling forgings at plant of Willys-Overland Co.

FOUNDING

LOCOMOTIVE CYLINDERS. Cylinders for Locomotives and Foundry Practice, M. Audo. Foundry Trade Jl., vol. 37, no. 587, Nov. 17, 1927, pp. 119-120, 3 figs. Difference between wear and hardness; influence of cooling conditions; error in correlative formula; effects of slight changes in composition. Au-

thor's written reply to paper read before Inst. of Brit. Foundrymen.

FOUNDRIES

AMERICAN. A German Foundryman's Impressions of American Foundry Practice (Streifzüge durch amerikanische Giessereien), T. Geilenkirchen. Giesserei, vol. 14, nos. 46, 47, 48, 49 and 51, Nov. 12, 19, 26, Dec. 3 and 17, 1927, pp. 805-807, 825-826, 839-841, 854-857 and 889-895, 44 figs. Based on visit to United States in 1926, author gives his impressions of leading American foundries. Nov. 12: Baldwin Locomotive Works, Eddystone, Pa.; Nov. 19: Westinghouse Co., South Philadelphia, Nov. 26: Westinghouse Air-Brake Co. and Standard Sanitary Co. in Pittsburgh. Dec. 3: National Mall. and Steel Castings Co., Cleveland, O. Dec. 17: Buick Motor Co., Flint, Mich.

AMERICAN. American Visit of European Iron and Steel Foundrymen in September and October 1926 (Von der Amerikafahrt europäischer Eisen- und Stahlgiesser im September und Oktober 1926), C. Irresberger. Stahl u. Eisen, vol. 47, nos. 8, 30, 34 and 39, Feb. 24, July 28, Aug. 25 and Sept. 29, 1927, pp. 289-293, 1241-1245, 1 fig. Review of main impressions; labor conditions; education and colleges; foundry show and International Foundrymen's Congress in Detroit; description of notable castings; reasons for American economic superiority. Description of foundry equipment exhibited in Detroit.

ECONOMICS. Foundry Economics (Sparquellen in der Giesserei), F. Dengler. Zeit. für die gesamte Giessereipraxis, vol. 48, nos. 38, 40, 41, 42 43 and 44, Sept. 18, Oct. 2, 9, 16, 23 and 30. pp. 329-331, 345-347, 353-355, 361-362, 369-370 and 377-378. Discusses practical significance of Koppers' experiments on coke combustion, removal of wastes, furnaces and their efficient operation, molding process, forms and casting, wage and bonus systems, piece work, Taylor methods.

QUANTITY PRODUCTION. The Quantity Production of Castings, A. S. Beech. Foundry Trade Jl., vol. 37, no. 590, Dec. 8, 1927, pp. 177-181, 13 figs. Points out that manufacturers themselves must embark on more progressive policy and accept standardization of their product; labor-saving machinery must be introduced wherever possible, and cost of electricity must be brought to lowest possible level; piecework or output bonus are inevitable for such a scheme.

TECHNICAL TERMINOLOGY. A Lexicon of Technical Terms. Foundry, vol. 55, nos. 4, 5, 6, 8, 9, 11, 12, 14, 15, 16, 17, 18, 19, 20 and 21, Mar. 1, 15, Apr. 15, May 1, June 1, 15, July 15, Aug. 1, 15, Sept. 1, 15, Oct. 1, 15 and Nov. 1, 1927, supp. plates. Foundry data sheets.

FUEL ECONOMY

IRON AND STEEL INDUSTRY. The Efficient Utilization of Fuel in Iron and Steel Works, H. E. Wright. Iron & Coal Trades Rev., vol. 115, no. 3116, Nov. 18, 1927, pp. 739-740. Deals with present usage, pointing out where savings are possible.

FURNACES, ANNEALING

CHARGING CRANES. Gantry Charging Crane. Iron Age, vol. 120, no. 24, Dec. 15, 1927, p. 1666, 2 figs. Equipment of new method of handling castings into annealing ovens has been installed by large heavy-machinery builder in Middle West, effecting, it is said, substantial reduction in handling costs; consists of single-leg gantry bridge upon which charging trolley of special design is operated.

FURNACES, FORGING

ELECTRIC. Electrically Heated Forging Furnace, H. G. D. Nutting. Elec. World, vol. 90, no. 24, Dec. 10, 1927, pp. 1201-1202, 2 figs. Installed in Detroit automobile-parts plant to heat steel for upsetting purposes; known as Berwick metal heater and made by Am. Car. & Foundry Co.

FURNACES, GAS

INDUSTRIAL. New Uses of Gas Heat in Industry, R. Trautschold. Factory, vol. 39, no. 6, Dec. 1927, pp. 1101-1108, 4 figs. Application to heating ovens, heat treating of steel, carburizing, annealing and core baking.

FURNACES, HEAT TREATING

DEVELOPMENTS. Furnace Development in Heat Treating and Forging, W. M. Hepburn. Am. Soc. for Steel Treater—Trans., vol. 13, no. 1, Jan. 1928, pp. 126-138 and (discussion) 138-141, 7 figs. Scientific developments in furnace equipment with particular reference to combustion, refractories, insulation, and temperature controls; outstanding modern gas-fired installations; trend of development has been to expand problem far beyond that of simple inventions into that of advancing science.

OIL-BURNING. Burning Oil in Heat Treating Furnaces. Fuel Oil, vol. 6, no. 6, Dec. 1927, pp. 27-28 and 140. There is no one type of burner suitable for all heating requirements; essential features are that it be properly proportioned to oil and air, or steam pressures available, and so designed that all parts are accessible and permit of close adjustment, cleaning, and convenient removal from furnace, without affecting operation of any other burner served by same piping system.

FURNACES, INDUSTRIAL

DESIGN. Practical Industrial Furnace Design, M. H. Mawhinney. Forging—Stamping—Heat Treating, vol. 13, no. 11, Nov. 1927, pp. 452-455, 3 figs. Furnace construction as it relates to members which are either castings or structural steel; physical characteristics of metals.

FURNACES, MELTING

DESIGN. A Note on Foundry Equipment, with Special Reference to Furnaces, C. A. Otto. Mech. World, vol. 82, no. 2133, Nov. 18, 1927, pp. 378-379. Review of developments in brass foundries, ordinary crucible furnaces are gradually being displaced by other furnaces of more up-to-date type, which are capable of dealing with much larger quantity of metal in considerably less time, taking up less space and requiring comparatively less labor to prepare metal; electric furnaces.

GEARS

CAST-IRON. The Influence of Elasticity on Gear-Tooth Loads. Mech. Eng., vol. 50, no. 1, Jan. 1927, pp. 65-67. Progress report no. 9 of A. S. M. E. special research committee on Strength of Gear Teeth. Test runs with cast-iron gears; calculated amounts of separation on these gears show much greater variations than on hardened and ground steel gears; in general, cast-iron gears show greater amounts of separation than semi-steel gears.

MANUFACTURE, METALLURGY IN. Metallurgy in Gear Manufacture, F. W. Rowe. Foundry Trade Jl., vol. 37, no. 588, Nov. 24, 1927, pp. 139-140. Cast iron for machine-cut gears must have maximum hardness consistent with good machining properties; composition limits; bronze gear-wheel blanks; advantages of centrifugal castings; case-hardening.

HARDNESS

INDICATORS. "Monotron" Constant-Diameter Hardness Indicator. Forging—Stamping—Heat Treating, vol. 13, no. 11, Nov. 1927, p. 468, 1 fig. For measurement of quantitative and qualitative hardness in metals and all other materials such as minerals, glass and organic compounds like rubber; instrument is static mechanical pressure machine acting on small diamond ball impressor through specially designed high-duty weigher or pressure scale.

TESTING. Hardness Testing (Ein Beitrag zur Haertepruefung), E. Franke. Kruppsche Monatshefte, vol. 8, Nov. 1927, pp. 179-187, 15 figs. Relation between Brinell and ball impact hardness, between Brinell and scratch hardness experimentally established.

TESTING. Hardness Testing Machines. Machy. (Lond.), vol. 30, nos. 765, 767, 774, 775 and 781, June 9, 23, Aug. 11, 18 and Sept. 29, 1927, pp. 312-314, 373-376, 597-599, 627-628 and 816, 28 figs. Review of apparatus available.

THIN PLATES. Determination of Ball-Pressure Hardness of Thin Plates (Ueber die Bestimmung der Kugeldruckhaerte von duennen Blechen), R. Mailaender. Kruppsche Monatshefte, vol. 8, Aug.-Sept. 1927, pp. 129-132, 3 figs. Experiments with brass and copper sheets; sheets tested are to rest on material of equal hardness or several sheets are to be superimposed.

HEAT TRANSMISSION

LAW OF SIMILARITY. Theory of Similarity of Heat Transmission (Zur Kritik der Aehnlichkeitstheorie des Wärmeübergangges) A. Schack. Stahl u. Eisen, vol. 47, no. 47, Nov. 24, 1927, pp. 1989-1990. Description and critical discussion of theory of similarity formulated in 1910 by W. Nusselt and further developed by H. Gröber; results of investigation of limits of validity of theory.

IRON

DIRECT PRODUCTION. The Direct Production of Pure Iron, P. Longmuir. Iron & Steel of Can., vol. 10, no. 12, Dec. 1927, pp. 370-371.

Historical sketch of various methods of making iron directly in furnace; discusses possibilities of direct reduction and its commercial advantages; touches Thomas Rowland's proposals for production of high purity metallic iron.

ELECTROLYTIC, MAGNETIC VISCOSITY. Fundamental Laws of Magnetic Viscosity Influence of aging and Annealing (Les lois fondamentales de la viscosite magnetique L' influence du vieillissement et des recuits), C. Lapp. Revue de Metallurgie, vol. 24, no. 9, Sept. 1927, pp. 496-508, 11 figs. Electrolytic iron exhibits phenomenon of magnetic viscosity common to ferromagnetic substances; viscosity is diminished by prolonged aging at 130 to 180 deg. but at expense of magnetic properties of metal; annealing at 300 to 500 deg. has inverse effect.

FUSION TEMPERATURE, EFFECT OF. Some Metallurgical Factors which May Have an Influence on Welds, Particularly on Iron, F. C. Thompson. Welding Jl., vol. 24, no. 289, Oct. 1927, pp. 310-315, and discussion in no. 290, Nov., pp. 342-344. Considers changes that occur in iron as it cools from fusion down to room temperatures; certain other effects of temperature and effects of gases. Paper read before Institution of Welding Engrs.

OLD PROCESSES. The Making and Rolling of Iron, J. W. Hall. Engineer, vol. 144, no. 3753, Dec. 16, 1927, p. 689. Review of early developments; how wrought iron was made, and how its cost was reduced, until mill of size suitable for rolling iron became commercially practicable; 1784 Henry Cort introduced his process of "dry" puddling on sand bottom in reverberatory furnace; last and greatest advance was made by J. Hall in 1839 in lining his puddling furnace with partially fusible oxide of iron, and boiling instead of baking his pig.

OXIDES. Oxides of Iron, Especially Ferrous Oxide (Beiträge zur Untersuchung der Oxyde des Eisens, besonders des Eisenoxyduls), H. Groebler and P. Oberhoffer. Stahl u. Eisen, vol. 47, no. 47, Nov. 24, 1927, pp. 1984-1988, 3 figs. Experimental production of ferrous oxide at Aachen Inst. of Technology, analysis, determination of melting point; X-ray investigations of oxides of iron.

IRON ALLOYS

CEMENTATION. Case Hardening of Ferrous Alloys with Boron (Cementation des alliages ferreux par le bore), J. Laissus. Revue de Métallurgie, vol. 24. no. 10, Oct. 1927, pp. 491-500, 16 figs. Study of different processes, iron-boron diagram; properties of ferrous alloys cemented with boron.

DEFERRIZATION. Deferrization of Ferrous Alloys (Sur un procédé de déferrage), B. Bogitch. Academie des Sciences—Comptes Rendus, vol. 185, no. 19, Nov. 7, 1927, pp. 1046-1048. Deferrization of iron alloys of copper, nickel and cobalt by process of pulverization.

IRON-CHROMIUM. The Diagram of State of Iron-Chromium Alloys (Zur Kenntnis des Zustandsdiagrams Eisen-Chrom), P. Oberhoffer and H. Esser. Stahl u. Eisen, vol. 47, no. 48, Dec. 1, 1927, pp. 2021-2031, 15 figs. Review of earlier investigations; X-ray analyses; testing equipment and methods for thermoanalytical tests; results and evaluation of tests; thermodynamic considerations.

IRON AND STEEL

ALLOYING MATERIALS. Iron and Steel Alloying Materials, J. M. Quinn. Foundry, vol. 55, nos. 22, 23 and 24, Nov. 15, Dec. 1 and 15, 1927 Foundry data sheet. Details and comments on ferroalloys. Dec. 1. Melting ranges of alloys.

CORROSION. Corrosion of Iron and Its Anodic Polarization (Die Korrosion von Eisen und seine anodische Polarisation), R. A. Dengg and H. J. Donker. Korrosion u. Metallschutz, vol. 3, no. 11, Nov. 1927, pp. 241-246, 4 figs. Experimental study of electrical phenomena and metallographic changes in ingot steels, Bessemer steel and pearlitic cast iron immersed in solution containing chloride and carbonate of potassium.

PROGRESS. Progress in the Iron and Steel Industry. Mech. Eng., vol. 50, no. 1, Jan. 1928, pp. 55-56. Report contributed by Iron and Steel Division of A. S. M. E. Manufacture of large seamless tubing; continuous sheet rolling; rolling mills; foundry developments.

IRON CASTINGS

HOLLOW CYLINDERS. New Process of Casting Thick Paper Cylinders (Neues Giessverfahren zur Erzielung dichter Papierzylinder), K. Lehmann. Giesserei, vol. 14, no. 48, Nov. 26, 1927, pp. 837-839, 2 figs. Describes new and successful process of casting long hollow cylinders, in which molten iron flows simultaneously over entire surface of cylinder in mold.

MICROSTRUCTURE. Special Micro-Structures in Iron Castings. Vestnik Metallopromisheennosty, no. 9, Sept. 1927, pp. 72-79, 13 figs. Metallographic and chemical study of cast iron water pipes of Russian manufacture which burst when tested. (In Russian.)

NICKEL AND CHROMIUM IN. The Economic Value of Nickel and Chromium in Gray Iron Castings, D. M. Houston. Am. Soc. for Steel Treat.—Trans., vol. 13, no. 1, Jan. 1928, pp. 105-120 and (discussion) 120-125, 12 figs. Silicon is graphitizer and softener; chromium is carbide former and, therefore, hardener; nickel is carbide destroyer and matrix hardener; in making use of nickel and chromium in foundry mixtures, author gives approximate equivalents to assist in determining nature of structure that may be obtained from alloy mixture compared with one of plain iron or semi-steel; importance of base composition as economic factor; illustrations of nickel-chromium mixtures developed with proper base composition whereby Brinell hardness was uniformly increased 20 to 30 points without impairing machinability at approximately same cost per pound as plain cast iron.

IRON, PIG

MICROANALYSIS. Elementary Micro-Analysis of Pig-Iron, H. Cowan. Foundry Trade Jl., vol. 37, no. 588, Nov. 24, 1927, p. 138. Suggestions to aid iron founder to interpret his observations on fractures of pig iron.

MAGNESIUM ALLOYS

HIGH-MAGNESIUM. High-Magnesium Alloys (Beitrag zur Kenntnis der hochprozentigen Magnesiumlegierungen), W. Schmidt. Zeit. für Metallkunde, vol. 19, no. 11, Nov. 1927, pp. 452-455, 24 figs. Laboratory studies of properties of following alloys; aluminum-magnesium, zinc-magnesium, lead-magnesium, manganese-magnesium.

MALLEABLE CASTINGS

BLACK-HEART. British Standard Specification for Black Heart Malleable Iron Castings. Brit. Eng. Standards Assn., no. 310, Nov. 1927, 7 pp., 2 figs. Not applicable to light castings which are to be subjected to hydraulic, steam or air-pressure tests; provision and heat treatment of test bars; size of test bars; mechanical tests; number of tensile and bend test bars; testing facilities.

BLACK-HEART. The Black Heart of Malleable Castings (Ueber den schwarzen Kern des Tempergusses), O. Quadrat and J. Koritta. Giesserei, vol. 14, no. 49, Dec. 3, 1927, pp. 849-854, 5 figs. Investigations of composition of original white iron and of black core, its mechanical properties and strength; influence of heat treatment on mechanical properties of black core; purpose of investigation was to determine conditions for heat treatment of black-heart malleable. (To be continued.)

WHITE-HEART. British Standard Specification for White Heart Malleable Iron Castings. Brit. Eng. Standards Assn., no. 309, Nov. 1927, 7 pp. Not applicable to light castings which are to be subjected to hydraulic steam or air-pressure tests; provision and heat treatment of test bars; size of test bars; mechanical tests.

COLD WORKING, EFFECT OF. Atomic Deformation in Cold Working of Metals (Atommodeformation bei bearbeiteten Metallen), W. Geiss and J. A. M. van Liempt. Zeit. für Physik, vol. 45, no. 9-10, 1927, pp. 631-634. Observations on electrical conductivity of tungsten wires showing that cold working causes deformation in atoms.

CONTRACTION. Contraction of Metals and Alloys (Ueber die Schwindung der Metalle und Legierungen), F. Sauerwald, E. Nowak and H. Jeretzek. Zeit. für Physik, vol. 45, no. 9-10, 1927, pp. 650-662, 5 figs. Experimental determination of linear contraction of solidified metals (lead, tin, aluminum, zinc, copper), alloys of copper and tin and gray cast iron.

DEGASIFICATION. Degasification of Metals and Its Relation to Corrosion, F. M. Dorsey. Indus. & Eng. Chem., vol. 19, no. 11, Nov. 1927, pp. 1219-1225, 9 figs. Commercial development of process devised by C. P. Madsen for degasification of metals and for subsequent plating in manner to produce continuous, homogeneous, protective metallic film; under certain conditions nickel plate which is soft, ductile, annealable, and malleable may be produced, thus permitting rolling, drawing, spot-welding, soldering, and other steps in fabrication of plated metal.

DIFFUSION IN SOLID STATE. Diffusion of Zinc in Copper and in Copper-Zinc Alloys at 350 Deg. Cent. (Diffusion von Zink in Kupfer und von Zink in Kupfer-Zink-Mischkristallen bei 350 deg. C.), W. Köhler. Centralblatt der Hütten Walzwerke, vol. 31, no. 45, Nov. 9, 1927, pp. 650-657, 13 figs. Theoretical and experimen-

tal study of diffusion in solid metals; diffusion coefficients. Bibliography.

ELECTRICAL INDUSTRY. Some Metallurgical Problems of the Electrical Industry, C. C. Paterson. Metal Industry (Lond.), vol. 31, nos. 20 and 21, Nov. 18 and 25, 1927, pp. 457-459 and 484-485. Metals and alloys used in electrical industry at present could be grouped roughly, as regards more important physical properties, as follows: electrical conductivity and tensile strength; magnetic permeability at low and at high flux densities; high-temperature resisting and electrical resistivity; underlying those considerations is practical consideration of cost, in relation to materials available; magnetic properties; effect of heat treatment and working on magnetic properties; impurities and their influence on properties; effect of gases on electrical properties.

ELECTRICAL PROPERTIES AT LOW TEMPERATURES. Electrical Behavior of Metals within Temperature Range of Liquid Helium (Das elektrische Verhalten der Metalle im Temperaturgebiet des flüssigen Heliums), W. Meissner. Zeit. für die gesamte Kälte-Industrie, vol. 34, no. 11, Nov. 9, 1927, pp. 197-205, 18 figs. Apparatus for liquefaction of helium at the Reichsanstalt, conductivity and field hysteresis, resistance of tin, lead, cadmium gold, etc., also of lead-tin alloys, at temperatures near absolute zero.

FATIGUE. Fatigue Phenomena with Relation to Cohesion Problems, H. J. Gough, Metal Industry (Lond.), vol. 31, no. 24, Dec. 16, 1927, pp. 557-561. For purposes of present note, fatigue phenomena is understood to be characteristics exhibited by metals when subjected to cyclical variations of stress or strain; fatigue tests on crytalline aggregates; deformation by slip; attrition theory; hardening as result of slip; test shows, broadly, that effect of boundary is mainly one of "interference" due to differing orientation of neighboring crystals; experiments upon effect of fatigue stressing upon density of aluminum.

MACHINABILITY. Machinability of Metals, O. W. Boston. Am. Soc. for Steel Treat.—Trans., vol. 13, no. 1, Jan. 1928, pp. 49-85 and (discussion) 86-94, 29 figs. Outline of various methods used to designate machinability; gives under heading of each method, outline of work done by various authors as published in few outstanding papers on subject; machinability may refer to relative machining qualities of several metals under same conditions or to those of given metal under varying conditions. Bibliography.

METALLOGRAPHIC ACCEPTANCE TESTS. Judging Plows by Metallographic Tests, P. J. Saldau and V. N. Semyonov. Vestnik Metallopromishlennosty, no. 9, Sept. 1927, pp. 171-195, 52 figs. Investigation of microstructure and mechanical properties of metal of most important parts of representative German makes; such investigations to be included in acceptance tests. (In Russian.)

MICROSCOPIC EXAMINATION. The Microscopic Examination of Engineering Materials, A. B. Everest. Rugby Eng. Soc.—Proc., vol. 1, 1926-1927, pp. 15-36, 31 figs. Demonstrates how microscope is becoming more and more basis of testing of many engineering materials; reference is made to microstructure of metals, and its relation to thermal and mechanical treatment of metal; in special case, relation between microstructure and physical properties of series of alloys is discussed, showing how, within limits, microscope can form basis of investigation of such series; micro examination of some special materials, notably of electrical insulators.

MOLTEN, CONTRACTION. Methods of Measuring Contraction, H. C. Dews. Foundry Trade Jl., vol. 37, no. 589, Dec. 1, 1927, p. 162. Changes in volume which occur in metal passing from temperature of molten liquid to that of solid casting are responsible for major portion of difficulties encountered by foundrymen who need to produce sound castings; review of investigations of volume changes and of density of liquid metals.

PUNCH TEST. Further Development of the Punch Test (Zur Weiterentwicklung des Stauchversuchs), E. Siebel. Zeit. für Technische Physik, no. 10, 1927, pp. 401-404, 9 figs. Ordinary punching produces very complex stresses and deformations, making it unsuitable as testing method; superiority of punching between conical surfaces; punching phenomena near elastic limit.

SHIPBUILDING. Marine-Engineering Constructional Materials (Materialfragen im Schiffsmaschinenbau), B. Schulz. Schiffbau, vol. 28, no. 20, Oct. 19, 1927, pp. 438-443. Discusses subject in four main groups: boilers, steam reciprocating engines, steam turbines and oil engines; and considers conditions and regulations governing choice of materials in each. See brief translated abstract in Mar. Engr. & Motorship Bldr., vol. 50, no. 604, Dec. 1927, p. 477.

SURFACE TREATMENT BY DIFFUSION. Surface Treatment of Metals by Diffusion (Die Oberflächenveredelung von Metallen durch Diffusion), G. Grube. Zeit. für Metallkunde, vol. 19, no. 11, Nov. 1927, pp. 438-447, 22 figs. Diffusion curves, diffusion of aluminum in iron, chromium in nickel, tungsten and molybdenum in iron; calculating coefficient of diffusion limits of resistance to chemical corrosion attainable by this process.

MICROSCOPY

ILLUMINATION IN. Illumination in Metal Microscopy, H. S. George. Optical Soc. of Am.—Jl., vol. 15, no. 5, Nov. 1927, pp. 295-304, 9 figs. Ideal method of illumination is advanced with specific means for its production in metallography; several types of apparatus are discussed and improved device is described; illustrated by diagrams and by studies of grain structure in solid solution.

MOLDS

CLOSING. Easier Mold Closing. Iron Age, vol. 120, no. 25, Dec. 22, 1927, p. 1718, 2 figs. Turnable in interrupted right-angle conveyor facilitates placing cope; development by Osborn Mfg. Co., Cleveland.

INGOT. Ingot Teeming Speed and Quality, E. G. Smith. Iron Age, vol. 120, no. 25, Dec. 22, 1927, p. 1725. Influence of

nozzle diameter and material, ladle depth, mold area and method of pouring.

MONEL METAL

WELDING. How to Weld Monel Metal. Oxy-Acetylene Tips, vol. 6, no. 5, Dec. 1927, pp. 86-88, 4 figs. Tells how to weld sheets, bars, and forgings, and castings.

NICKEL

VISCOSITY. Viscosity of Nickel, Aluminum and Light Alloys (Essais de viscosité sur le nickel, l'aluminium et les alliages légers), J. Cournot and M. S. Silva. Académie des Sciences—Comptes Rendus, vol. 185, no. 14, Oct. 3, 1927, pp. 650-652. Viscosities of commercial nickel, "calypso," aluminum, "alpax" and duralumin wires of varying diameters have been studied at 15 to 700 deg. by method previously described.

NICKEL ALLOYS

CORROSION-RESISTING. Nickel Alloys and Corrosion, M. Porterin, Iron & Coal Trades Rev., vol. 115, no. 3118, Dec. 2, 1927, p. 828. Points out that nickel and chrome-steel alloys, which are malleable and specially resistant to corrosion, either alone or with small additions of molybdenum, tungsten, etc., and particularly nickel-chrome austenitic steel, are destined to play increasingly important part in resistance to corrosive agents. See also Foundry Trade Jl., vol. 37, no. 590, Dec. 8, 1927, p. 183. Translated from French.

NICKEL CAST IRON. Nickel Cast Iron, A. E. Hanson and E. J. Bothwell. Tech. Eng. News, vol. 8, no. 6, Nov. 1927, pp. 258-259 and 278, 4 figs. Description of properties of this new alloy, with reference to its economical use as engineering material.

OPEN-HEARTH FURNACES

AIR PREHEATERS. Preheaters for Open-Hearth Furnaces and Their Relation to Waste Heat Boilers, W. Dyrssen. Min. & Met., vol. 9, no. 253, Jan. 1928, pp. 12-17, 7 figs. Hotter combustion air with less temperature variation during reversal period is desirable; advantages of metal air preheaters.

ISLEY CONTROL. The Isley Furnace Control, G. A. Merkt. Min. & Met., vol. 8, no. 252, Dec. 1927, pp. 502-507, 6 figs. Substitution of Venturi throat for ordinary chimney permits positive adjustment of draft and leads to better heat recovery; open-hearth steel furnace is only one of many kinds of furnaces which lends itself to this type of furnace control.

REGENERATORS. Kuehn Open-Hearth Regenerators. Iron & Coal Trades Rev., vol. 115, no. 3119, Dec. 9, 1927, p. 868. Results from 30-ton furnace rebuilt and equipped with Kuehn regenerators at very moderate cost.

OXYACETYLENE CUTTING

ECONOMICAL APPLICATIONS. Economical Oxyacetylene Cutting Needs Intelligent Supervision, J. L. Anderson. Iron Trade Rev., vol. 81, no. 23, Dec. 8, 1927, pp. 1421-1423 and 1428, 3 figs. Calls attention to importance of oxyacetylene cutting process from oxygen-consumption standpoint; considers factors that enter into economical application of this process.

OXYACETYLENE WELDNG

AIRCRAFT. Principles of Aircraft Welding, P. N. Jansen. Acetylene Jl., vol. 29, no. 6, Dec. 1927, pp. 238-240, 5 figs. Methods used by Curtiss Airplane and Motor Co. are described with types of joints and personnel of welders.

AIRCRAFT. Welded Aircraft, T. C. Fetherston. Am. Welding Soc.—Jl., vol. 6, no. 11, Nov. 1927, pp. 15-27, 24 figs. Details of welded joints on airplanes, using oxyacetylene; saving of weight; describes types of joint and advantages of welding.

ENGINE CASTINGS. Oxyacetylene Welding of Oil Engine Castings. Oil Engine Power, vol. 5, no. 12, Dec. 1927, pp. 829-830, 1 fig. Problems involved in welding large complicated gray-iron castings such as are used in oil engines consist mainly in controlling heat of welding operations so that there will be no warping out of true nor cracking due to internal stresses.

GALVANIZED TANKS. Gas Welding Galvanized Tanks. Welding Engr., vol. 12, no. 11, Nov. 1927, pp. 39-40, 9 figs. Production methods which make it a simple matter to keep finished article up to standard; system of welding has been perfected which not only simplifies job of assembling but results in homogeneous construction in which strains are equalized and resulting tank is as strong as it looks.

HYDROELECTRIC PLANTS. Keeping Ahead of Schedule in Hydroelectric Plant Construction. Oxyacetylene Tips, vol. 6, no. 5, Dec. 1927, pp. 90-97, 35 figs. Treats of all applications of welding to construction work as well as cutting of steel by blow pipe.

STAINLESS STEEL. Gas Welding Stainless Steels, C. B. Callomon. Acetylene Jl., vol. 29, no. 6. Dec. 1927, pp. 229-231, 2 figs. Some properties of chromium alloys make them difficult to weld by ordinary methods, but excellent results have been obtained by improved practices discussed; describes alloy called Ascoloy 33, its properties and methods of welding it.

STEEL PIPE. Welded Pipe Becoming Standard, L. Stein. Welding Engr., vol. 12, no. 11, Nov. 1927, pp. 25-27, 7 figs. Lead-proof construction is most important; welded lines are better adapted to varied conditions; more resistance to stresses and corrosion; practice of making oxyacetylene welded points in gas mains while not new has been found to be of greater interest to gas engineer during past six or eight years.

STELLITING. Two Metals Better Than One. Acetylene Jl., vol. 29, no. 6, Dec. 1927, pp. 241-243, 2 figs. Methods employed to weld stellite to oil-well drills by oxyacetylene process; advantages in oil drilling work; reports of bits in practice and stelliting in oil field shops.

TANKS. How to Weld a Cylindrical Steel Tank, E. R. Doyle. Sheet Metal Worker, vol. 18, no. 22, Dec. 2, 1927, pp. 812-813 and 826, 7 figs. Advantages of using oxyacetylene process in tank construction; comparison of welded with riveted tanks.

PIPE, CAST-IRON

BRONZE WELDING. Bronze Joints in Cast Iron Pipe, T. C. Fetherston. Iron Age, vol. 120, no. 26, Dec. 29, 1927, pp. 1782-1784, 4 figs. Four years' service experience indicates weaknesses in butt joints with collar welds; new "shear-vee" design proves cheaper and twice as strong.

BRONZE WELDING. New Bronze Joint Has High Strength, T. W. Greene. Acetylene Jl., vol. 29, no. 6, Dec. 1927, pp. 246-248, 5 figs. Comparison of three types of welded pipe joints, collar type joint failures analyzed, advantages of Shear-Vee joint.

PIPE, STEEL

WELDED. A Physical Study of the Mokelumne Pipe Line, L. T. Jones and W. A. Weeks. Univ. of California Publications in Eng., vol. 2, no. 9, Oct. 20, 1927, pp. 277-356, 60 figs. 65 in. pipe line 80 miles long, acetylene and electric welded; study of causes of failure and report on their programs for laying welding and back filling of pipe.

PYROMETERS

TYPES. Measurement of Temperatures by Optical and Radiation Pyrometers (Les measures des temperatures au moyen des pyrometres optiques et a radiations), J. Vassilliere-Arlhac. Electricite & Mecanique, no. 20, Sept.-Oct. 1927, pp. 35-41, 7 figs. Discusses principles and types; treats of standardization of pyrometers and causes of error in measurements, also precision obtained by various types, especially that of Riband.

RAILS

STEEL. Are We Making Progress in Rail Service, C. B. Bronson. Ry. Age, vol. 83, no. 24, Dec. 10, 1927, pp. 1155-1156. Table giving relationship of N. Y. Central locomotives to rail sections; new steels are being developed and weight increased faster than loads.

TRANSVERSE FISSURES. Transverse Surface Cracks in Rails (Les fissures transversales superficielles des rails), H. Viteaux. Revue de Métallurgie, vol. 24, nos. 9, 10 and 11, Sept., Oct. and Nov. 1927, pp. 485-495, 601-618 and 671-682, 28 figs. Historical sketch of observations, original observations and impact tests showing great weakening effect of such cracks; study of remedial measures.

RAILWAY TIES

STEEL. Restate Steel Tie Question. Iron Age, vol. 120, no. 25, Dec. 22, 1927, p. 1721. Writer puts problem up to steel industry and not railroads; need of determining form of greatest economic value.

REFRACTORIES

DEVELOPMENTS. Developments in Refactories, S. M. Phelps. Fuels & Furnaces, vol. 5, no. 12, Dec. 1927, pp. 1651-1652. Possibilities for advancement in refractory fuels; various refractories and their future development. Abstract of paper presented at Iron & Steel Division of Am. Soc. Mech. Engrs.

FOUNDRY. Manufacture of Refractory Bricks for Ports and Channels of Foundry Furnaces (Die Kanalsteinfabrikation), B. Euler. Tonindustrie-Zietung, vol. 51, no. 82 and 83, Oct. 12 and 15, 1927, pp. 1491-1492 and 1511-1512, 9 figs. Details of raw materials, preparation, and of equipment and its arrangement.

FOUNDRY. Refractory Materials in Foundry Work (Die feuerfesten Materialien im Giessereibetrieb), C. Mado. Zeit. fuer die gesamte Giessereipraxis, vol. 48, no. 48, Nov. 27, 1927, pp. 410-412, 5 figs. Classification of foundry refractories and methods of protecting them with rare earth compounds, such as "Eydamit", manufactured by Timpe & Co., Berlin.

HEAT EXPANSION. The Heat Expansion of Refractory Materials (Die Wärmeausdehnung von feuerfesten Baustoffen), K. Schönert. Archiv für das Eisenhüttenwesen, vol. 1, no. 5, Nov. 1927, pp. 379-386, 17 figs. Expansion of silica brick, firebrick and other refractories. Bibliography.

METALLURGICAL FURNACES. Silica and Magnesite Bricks in Metallurgical Furnaces, G. Wolff. Metal Industry (N. Y.), vol. 25, no. 12, Dec. 1927, pp. 489-492. Properties and requirements of these refractories for metal melting.

ROLLING MILLS

BACKED-UP. Mills of the Backed up Type Remove Cold Rolling Limitations, L. Jones. Iron & Steel Engr., vol. 4, no. 12, Dec. 1927, pp. 498-500. Explains types of backed-up mills; their advantages and reasons for adoption in rolling sheet metal; history of installation of backed-up mills and how they effected production.

BLOOMING MILLS. Reversing-Blooming-Mill Practice, G. A. Russell, . Mech. Eng., vol. 49, no. 12, Dec. 1927, pp. 1331-1334. Résumé of current practice, dealing with cogging, drafting practice, driving main rolls, reversing steam engines and motor drives, mill-train design, etc.

EFFICIENCY CALCULATION. Figuring Efficiency of Steel Mills, F. C. Smith. Iron Age, vol. 120, no. 26, Dec. 29, 1927, pp. 1781 and 1828. Method of calculating for rolling; allowing for lost time, cobbles, changing sections, etc.

ELECTRIC DRIVE. Frequency Converter Speed Sets for the Carnegie Steel Company, Upper Union Works, Youngstown, Ohio, G. P. Wilson. Iron & Steel Engr., vol. 4, no. 12, Dec. 1927, pp. 487-490, 6 figs. Describes electric motor equipment to drive merchant mills; driving unit consists of main motor with frequency converter on same shaft and transformer; speed regulation is same as induction motor.

Recent Developments in Electric Drives for Rolling Mills, L. A. Umansky. Mich. Technic, vol. 41, no. 1, Nov. 1927, pp. 7-9 and 21, 3 figs. D.c. and a.c. drives for continuous rolling in continuous mills.

ELECTRICAL EQUIPMENT. Electrical Equipment of Plate Mills. Elecn., vol. 99, no. 2582, Nov. 25, 1927, pp. 653-654, 4 figs. Details of recent installation which includes nearly 300 motors; advantages of d.c. motors for live rolls, etc.; reversing motors and flywheel equalizer sets.

MANNESMANN TUBE. Diagonal Rolling of Billets Into Seamless Tubes. Iron &

Steel World, vol. 1, nos. 4, 6, 7, 8 and 9, May, July, Aug., Sept., and Oct. 1927, pp. 261-266, 395-398, 469-478 and 639-645, 35 figs. Based on information obtained by German Iron & Steel Inst. during an investigation of forming processes involved in manufacture of seamless tubes from solid billets by diagonal rolling. May: Principles of diagonal rolling; stress to which stock is subjected and mechanical-dynamic processes; influence of mandrel; design of rolls. July: Forces acting at high point of rolls in diagonal rolling; torsion; compression and friction forces. Aug.: Microscopic investigation of sections of partially rolled billets to determine effects of diagonal rolling process. Oct.: Cross sectional changes in area; twisting of fibers.

SAND BLASTS

FOUNDRY. New Sand Blast Machinery (Neuanordnungen von Sandstrahlgebläsen), U. Lohse. Stahl u. Eisen, vol. 47, no. 47, Nov. 24, 1927, pp. 1973-1976, 6 figs. Describes sand blasts combined with drums or turntables, manufactured by Badische Maschinenfabrik, Durlach, designed for use in foundries.

SAND, MOLDING

MILLING AND HANDLING. Sand Milling and Handling, H. F. Coggon. Foundry Trade Jl., vol. 37, no. 589, Dec. 1, 1927, pp. 153-155 and (discussion) 155-156, 6 figs. Liquid core binders; mixing of sands; mechanicalized handling.

SEMI-STEEL

CASTING. Casting Semi-Steel Machine Tool Parts, E. G. Brock. Can. Foundryman, vol. 18, no. 12, Dec. 1927, pp. 7-11, 3 figs. Woodworking machinery and machine-tool parts weighing many tons, with 33 per cent higher tensile strength than gray iron, are produced from semi-steel mixtures, resulting in cleaner, more easily machined castings.

SHEET STEEL

ENCYCLOPEDIA. Encycopedia of Sheet Steel Shows Complexity of Uses. Iron Trade Rev., vol. 81, no. 26, Dec. 29, 1927, pp. 1610-1611. Review of book issued by Sheet Steel Trade Extension committee entitled "5000 Sheet Steel Products and Who Make Them".

STAYBOLTS

MATERIALS. Staybolt Materials Compared. Iron Age, vol. 120, no. 26, Dec. 29, 1927, pp. 1785 and 1829, 2 figs. Two independent investigations on wrought iron, steel and alloy steels; conditions under which staybolts are used.

TESTING. Observations on Testing of Sheet Steel. Forging—Stamping—Heat Treating, vol. 13, no. 11, Nov. 1927, pp. 435-438, 2 figs. Comparison of testing methods and internal defects noted in deep and extra-deep drawing of sheet steel; segregation, inclusions, etc., considered.

STEAM TURBINES

CONSTRUCTION MATERIALS. Turbine Construction Materials (Die Baustoffe der Schiffsturbine), E. A. Kraft. Schiffbau, vol. 28, no. 21 and 23, Nov. 2 and 7, 1927, pp. 463-466 and 545-548. Examines cast iron and special steels as construction materials for casings, shafts, wheels, etc.; correct methods of taking test specimens of turbine parts.

SPINDLE MANUFACTURE FOR. Building Large Steam Turbine Spindles, J. P. Rigsby. Elec. Jl., vol. 24, no. 12, Dec. 1927, pp. 591-596, 7 figs. Design, manufacture and operation; forging and heat treating; blading; balancing; overspeed test and final heat treating.

STEEL

CASE-HARDENING. A New Case-Hardening Mild Steel. Automobile Engr., vol. 17, no. 236, Dec. 1927, p. 516, 1 fig. Steel known as Jalcase combining strength and toughness with easy machining qualities.

CASE-HARDENING. Automobile Case-Hardening Steel. Engineering, vol. 124, no. 3231, Dec. 16, 1927, p. 796. British Rolling Mills, Brymill Steel Works, have placed on market case-hardening steel, designated CHIO steel; material has long and fine fibrous structure, it is homogeneous, and as free from slag as it is possible to make steel under commercial conditions; material is specially recommended for gudgeon pins and for other automobile-engine parts.

CEMENTATION. New Methods of Cementation (Nouvelles méthodes de cementation), H. Savage. Revue Universelle des Mines, vol. 16, no. 6, Dec. 15, 1927, pp. 253-274, 8 figs. Gaseous cementation; composites of iron and nitrogen; Krupp process of nitration; cementation with chromium.

COMPLAINTS FROM CONSUMERS. Complaints from the Consumer of Steel, J. R. Miller. Blast Furnace & Steel Plant, vol. 15, no. 12, Dec. 1927, pp. 575-576. Causes for many of troubles arising between purchaser and manufacturer of steel are pointed out and made impressive by experiences from actual practice.

DENSITY. Density of Hot-Rolled and Heat-Treated Carbon Steels, H. C. Cross and E. E. Hill. U. S. Bur. Standards—Sci. papers, no. 562, Oct. 11, 1927, pp. 451-466, 7 figs. Density values for commercially pure and electrolytic iron and series of carbon steels, varying from 0.09 to 1, 29 per cent carbon; values are given for these steels when hot-rolled, when annealed, when quenched, and when quenched and tempered. Bibliography.

MANGANESE IN. Determination of Manganese in Steels and Alloys Containing Large Portions of Chromium or Cobalt (Dosage du manganèse dans les aciers ou alliages renfermant de fortes proportions de chrome ou du cobalt), E. Rousseau. Chimie & Industrie, vol. 18, no. 5, Nov. 1927, pp. 772-780. Methods of adding manganese to steel having large chromium content; Travers method and method author used; stainless steel; methods for steel containing cobalt.

MOLYBDENUM IN. Colorimetric Determination of Molybdenum in Steel (Colorimetrische Bestimmung des Molybdaens im Stahl), J. Kassler. Chemiker-Zeitung, vol. 51, no. 98, Dec. 10, 1927, pp. 953-954. Method based on color reaction of molybdate ion with potassium thiocyanate and stannous chloride in acid solution, molybdenum being extracted from steel by means

of caustic soda; procedure in case of vanadium steels and steels not containing vanadium; sufficiently accurate determinations made in 25 or 30 min.

OIL-WELL DRILLING EQUIPMENT. Selecting Steels for Oil-Well Drilling Equipment for Known Performance, B. Gray and F. E. Cherry. Oil Field Eng., vol. 2, no. 8, Dec. 1927, pp. 34-41, 9 figs. Relationship between mechanical properties of steel and performance in field; influence of composition and heat treatment on mechanical properties of steel; selection of appropriate oil-well steels.

STAINLESS. Fighting the Rust Enemy. English & Amateur Mechanics, vol. 3, no. 57, Nov. 25, 1927, pp. 81-82 and 95. Recent developments in stainless steel; some interesting applications.

TENSION TESTING. Initial Set in Steels (Conditions d'apparition des lignes de cession marquant le début des déformations permanentes), J. Seigle. Génie Civil, vol. 90, no. 24, June 11, 1927, pp. 576-578, 18 figs. Specimens include bars for tension tests with suddenly enlarged sections and bars in which there is local hardening; various steels of different composition and subjected to different heat treatment were also tested; bars were tested in tension after local hardening had been effected either by Brinell imprint or by light hammering; in every case cracks were observed first in region of hardened part. See brief translated abstract in Mech. World, vol. 82, no. 2132, Nov. 11, 1927, p. 361.

MANUFACTURE. Steel Making with Special Reference to the Manufacture of Steel Castings, J. Deschamps. Foundry Trade Jl., vol. 37, no. 587, Nov. 17, 1927, pp. 125-127. Describes various processes used at present in steel foundries for production of plain carbon steels and discusses their respective merits and disadvantages. See discussion in Foundry Trade Jl., vol. 37, no. 588, Nov. 24, 1927, pp. 141-142.

PROPERTIES AND USES. Cast steel as a Construction Material (Der Stahlguss als Werkstoff), P. Bardenheuer. Archiv für Wärmewirtschaft, vol. 8, no. 11, Nov. 1927, pp. 333-334. Historical development of steel castings; microstructure, mechanical properties and practical uses of cast steel, its resistance to high temperatures and chemical corrosion.

STEEL, HEAT TREATMENT OF

ANNEALING. Open Discussion on Annealing. Metal Industry (Lond.), vol. 31, no. 21, Nov. 25, 1927, pp. 491-493. Discussion held in connection with co-ordinated societies (Staffordshire Iron and Steel Inst., Birmingham Metallurgical Society, and local section of Inst. of Metals); intermittent and continuous working compared; electric annealing furnaces; ecomomies of continuous annealing; muffle-furnace annealing; uncertainty in temperature control.

CASTINGS AND FORGINGS. High Temperature Treatments of Castings and Forgings as Evidenced by Core Drill Tests from Heavy Sections, W. J. Merten. Am. Soc. for Steel Treat.—Trans., vol. 13, no. 1, Jan. 1928, pp. 1-21 and (discussion) 21-28, 25 figs. Results of investigations to determine correct thermal treatments for improvement of grain structure of heavy-section steel castings; study of limitations of current practice of evaluating physical properties of large steel castings and forgings from comparatively small coupon tests; experimental data supported by microscopical analysis of complete and partial refinement respectively of grain structure of steel castings near surface and center of section show that considerably higher temperature, and extended soaking periods greater than "current ones" are necessary for proper adjustment and alteration of grain structure to permit use of higher service stresses in design of large-size electrical machinery; suggestions for recommended practice of heat treatment.

ELECTRIC HARDENING. Electrifying the Hardening Room. Iron Age, vol. 120, no. 23, Dec. 8, 1927, pp. 1584-1586. 100 per cent electric heat treatment of steel practiced in some plants; economic and other advantages brought out at Yale Conference, New Haven, Conn.; Pratt & Whitney hardening-room equipment; production costs reduced by electricity.

GEAR HOBS. Cutting and Heat-Treating Gear Hobs, D. M. Duncan. Can. Machy., vol. 38, no. 22, Dec. 1, 1927, pp. 17-19. Discussion of problems incident to production of accurate gears and gear-cutting tools, together with description of methods of machining and heat treating employed by Ontario concern.

HARDENING. The Water Hardening of Tool Steels, A. Mumper. Forging—Stamping—Heat Treating, vol. 13, no. 11, Nov. 1927, pp. 444-446, 3 figs. Author's experiences in handling steel of various descriptions; suggestions for improving practice.

INGOTS. The Influence of Heat Treatment of Mild-Steel Ingots before Rolling on Structure and Strength of Material (Der Einfluss der Wärmebehandlung von Weichstahlblöcken vor dem Auswalzen auf die Gefügeausbildung und die Festigkeitseigenschaften des Werkstoffes), H. Bitter. Archiv für das Eisenhüttenwesen, vol. 1, no. 5, Nov. 1927, pp. 371-378, 20 figs. partly on supp. plates. Influence of cooling of Thomas steel ingots previous to hot working on mechanical properties, structure and segregation; testing of results on about 100 steel ingots.

JAIL CONSTRUCTION. Heat Treating Steel for Jail Construction, P. J. Pauly. Iron Trade Rev., vol. 81, no. 24, Dec. 15, 1927, pp. 1481-1482, 2 figs. Methods and equipment of Pauly Jail Building Co., St. Louis; cell construction consists of sections of steel bars and plates riveted together; heat-treating department has two large gas furnaces for hardening steel plates but which are used interchangeably for carbonizing drop-forged steel hinges, small bars and other items, which must be toolproof.

OIL-WELL CASINGS. The Heat Treatment of Oil Well Casing, F. G. Tickell and W. J. Crook. Oil Field Eng., vol. 2, no. 7, Nov. 1927, pp. 25-35 and 47, 32 figs. Discusses physical properties of tubular goods used in oil wells with relation to stresses imposed and indicates possibilities in improvement of physical properties.

QUENCHING. On a New Method of Quenching Steels in a High Temperature Bath, K. Honda and K. Tamuru. Am. Soc. for Steel Treat.—Trans., vol. 13, no. 1, Jan. 1928, pp. 95-104, 7 figs. Method of quenching steels in hot media so that they may obtain troostitic or sorbitic structure directly, without tempering as is now done, after steel is water or oil-quenched; by using hot quenching media there is also little chance of quenching cracks being formed; structure of steel quenched in bath at about 930 deg. Fahr. is sorbitic; mechanical properties are not inferior to those of steel quenched in water and then tempered.

TEMPERING. New Theories in Tempering Steel, A. Heller. Am. Mach., vol. 67, nos. 21, 23 and 25, Nov. 24, Dec. 8 and 22, 1927, pp. 797-799, 903-907 and 971-974, 13 figs. Physical properties in steels used in parts are of great importance to machine builder; author explains how some of these properties are developed; Nov. 24: Heating steel for hardening; cause of brittleness; effect of rapid cooling. Dec. 8: Commercial tool steel; changes due to hardening and drawing; warping and bulging causes. Dec. 22: Color method of tempering steels; effect of time variations on color and hardness; control of temperature by fusible alloys; proper drawing temperatures.

TUBES. The Effect of Heat Treatment on Cold-Drawn Steel Tubes, F. C. Lea. Engineering, vol. 124, no. 3232, Dec. 23, 1927, pp. 797-800, 16 figs. Experiments to determine effect of annealing at various temperatures on properties of cold-worked steel tubes and their relationship to fatigue range; compression and torsion tests; change of density by heat treatment; effect of repetition stresses; effect of gradually raising repeated stress. (To be continued)

STEEL MANUFACTURE

BASIC. Employs Unique Methods in Making Basic Steel, J. D. Knox. Iron Trade Rev., vol. 81, no. 26, Dec. 29, 1927, pp. 1603-1606, 4 figs. 100-ton tilting open-hearth furnaces installed at Fordson plant of Ford Motor Co.; methods of handling raw material and of pouring steel differ from those followed by average open-hearth department.

CRUCIBLE MELTING. Crucible Tool Steel Melting by High Frequency Current. Machy. Market, no. 1415, Dec. 16, 1927, pp. 25-26, 5 figs. Describes plant and process of making tool steel in Sheffield, England; crucible holds 500 lb. and contents can be melted in 55 min., 20 tons per week output; electric current 1200 volt at 2200 periods per sec.

MELTING STAGE. The Melting or Molten Stage of Steel Manufacture with Particular Reference to the Deoxidizing, Refining and Contamination Phases, G. A. Dornin. Am. Soc. for Steel Treat.—Trans., vol. 13, no. 1, Jan. 1928, pp. 29-34 and (discussion) 34-48, 1 fig. Brings out extremely bad effects of oxides in steel and points to only known methods for their removal from molten bath; discusses various steel-melting processes and shows their possibilities for good steel making as shown by their capacity to make steel free from or relatively free from oxides; states that unless steel is properly melted it will not solidify properly nor can it be properly treated.

STEEL WORKS

CRANES. Some Modern Types of Steel Mill Cranes, W. D. Keller. Iron & Steel Engr., vol. 4, no. 12, Dec. 1927, pp. 506-508. Describes features of overhead traveling cranes; 4-girder type used for ladles; one-piece trolly and use of worm gears advocated; anti-friction bearings used; interlocked gear type of trolley.

SYDNEY, N. S. What the Eyes Behold at Sydney Steel Plant, W. S. Wilson and A. P. Theurkauf. Iron & Steel of Can., vol. 10, no. 11, Nov. 1927, pp. 331-341, 12 figs. Describes trip through steel plant of Dominion Iron & Steel Co.; details of coke ovens, shipping piers, blast furnaces, open-hearth steel furnaces, blooming, billet, rail, bar, rod and wire and rails mills.

STRUCTURAL STEEL

CONCRETE, VS. Steel and Concrete Engineering, R. Modjeski. Can. Engr., vol. 53, no. 22, Nov. 29, 1927, pp. 573-574. Relative merits of steel and reinforced concrete construction discussed in paper presented at fifth before Am. Inst. of Steel Construction.

CONSTRUCTION DEVELOPMENTS. Steel Construction Developments in 1927, L. H. Miller. Can. Machy., vol. 38, no. 22, Dec. 1, 1927, pp. 27-29. Outlines progress in fireproofing of structural steel, welding to replace riveting, study of wind stresses; and in standardization of light steel floor construction.

DURABILITY. The Dangers of Corrosion. Engineering, vol. 124, no. 3231, Dec. 16, 1927, pp. 770-771. Review of paper by F. W. Skinner on "The Unlimited Potential Durability of Structural Steel" read before Brooklyn Engineers' Club, which amply disproves possibility of any danger from corrosion in structures, which are designed to comply with present standards and are properly protected, inspected and maintained; paper established beyond doubt suitability of steel for both bridges and buildings.

TEMPERATURE CONTROL

AUTOMATIC REGULATORS. The Role of Temperature-Regulating Apparatus (Du role des appareils de la température), M. F. Jombart. Revue de Métallurgie, vol. 24, no. 10, Oct. 1927, pp. 573-578, 6 figs. Gives general idea of actual possibilities of temperature regulators, fundamental characteristics; study of various methods of regulation and critical examination of advantages and inconveniences of each one.

TOOL STEEL

VANADIUM AND COBALT ADDITIONS. The Influence of Cobalt, Vanadium and Manganese on the Properties of Tool Steel (Der Einfluss von Kobalt, Vanadin und Mangan auf die Eigenschaften von Werkzeugstahl), R. Scherer. Stahl u. Eisen, vol. 47, no. 48, Dec. 1, 1927, pp. 2035-2036. Investigations demonstrate that vanadium, silicon and cobalt additions are often very desirable.

News of the Society

SUMMARY OF EXTENSION COURSE

FOR several years the Board of Directors of the American Society for Steel Treating have felt a demand on the part of many chapters for a workable plan of carrying on some sort of an extension course covering the fundamentals of iron and steel refinement and fabrication. About a year ago the Board selected Professor John F. Keller of Purdue University as one admirably fitted for this work.

He came with the Society on August 1, 1927, and with the hearty co-operation of Purdue University, organized two lecture series of five centers each and delivered his six lectures in each center, one lecture a week. The results have been very gratifying. The statistics concerning the two lecture groups are as follows:

Group I September 1 to October 14	No. of men registered	Percentage attendance	Group II October 21 to December 16	No. of men registered	Percentage attendance
Canton-Massillon	92	90	Chicago	213	94
Columbus	46	92	Milwaukee	213	92
Dayton	98	94	Rockford	109	95
Erie	68	95	Tri Cities	132	94
Youngstown	59	91	South Chicago	181	86
Total	363	Average 92	Total	848	Average 91

Classification of Enrollment by Occupation

	Group I	Group II	Total	Percentage
Shopmen	92	190	282	23.3
Foremen	81	175	256	21.3
Superintendents	44	115	159	13.1
Engineers	37	119	156	13.0
Draftsmen	16	72	88	7.3
Metallurgists	20	35	55	4.5
Managers	11	23	34	2.8
Sales Representatives	3	28	31	2.5
Accountants	2	..	2	.1
Purchasing Agents	1	14	15	1.2
Presidents	2	10	12	.9
Chemists	17	42	59	4.9
Miscellaneous	37	25	62	5.1
	363	848	1211	100.0
Number of firms represented	54	143	197	

Registration in each center was representative of the iron and steel industries of that community. Three concerns in particular contributed large enrollments: National Cash Register Company, Dayton, Ohio, with 83 men; Wisconsin Steel Works of The Industrial Harvester Company, South Chicago, 129 men; and the Illinois Steel Company, South Chicago, 52 men.

An Engineering Extension Division Class

A summary of each lecture follows:

Lecture 1. Manufacture of iron and steel; methods of identifying various analyses.

Lecture 2. Demonstration of the "spark test", and its interpretation, the basic principles of forging, and flow of metals; the effect of heat and work on the crystalline structure of iron and steel.

Lecture 3. Annealing; refining of crystalline structure; annealing of chains, bolts and machine parts.

Lecture 4. The solid solution theory and the iron-carbon diagram in simple form; effective demonstration of the critical point and its importance to tool hardening and heat treating generally.

Lecture 5. Quenching media and their functions; tempering to develope toughness and to relieve quenching strains; the principal micro-constituents, briefly presented.

Lecture 6. Why iron and steel warp and crack; warpage of castings in cooling; autogeneous methods of welding, both gas and the electric arc.

These lectures were given at the approximate cost of $10.00 per man, $4.00 of which could be used to select reprints, data sheets and other A. S. S. T. publications. Purdue University presented a certificate to all who attended 80 per cent of the lectures. Both Professor Keller and the Society have received many letters of commendation and appreciation of this work.

These two lecture groups were so successful that others will probably be organized in the fall of 1928, provided there is a demand from a sufficient number of centers and provided that Professor Keller is again available.

SEMI-ANNUAL MEETING AT MONTREAL

ALL arrangements have been completed for the Semi-Annual Meeting of the Society, which will be held in the city of Montreal, Thursday and Friday, February 16 and 17, 1928, with headquarters at the Mount Royal Hotel.

On the following pages there appears a complete program of the events and the complete schedule of the technical papers to be presented. All technical sessions will be held in the Mount Royal Hotel, three of which are scheduled for Thursday and the balance for Friday. Inasmuch as the Semi-Annual Meeting replaces the two sectional meetings formerly held by the Society, the program of technical papers has been augmented with a total of fifteen papers, whereas at the previous sectional meetings the number presented has been seven or eight. It will be observed from the schedule of papers that a very comprehensive and broad scope has been included in the selection of these papers, and the members of the Society will profit very decidedly by attending this meeting.

In order that the additional number of technical papers could be presented, fewer plant inspection trips have been scheduled, than on the usual sectional meeting programs, but for those members who desire to visit plants in addition to those scheduled, Saturday will provide a suitable time for such inspections.

The Winter Sports for which Montreal is famous will be in full swing during this meeting, and those who would like to indulge in skiing or tobogganing may have the thrill of traveling at a rate of sixty miles per hour on the huge toboggans which Montreal boasts.

Montreal is especially accessible to the New England States being only an over-night trip, and it is urged that all members who possibly can attend the meeting, do so, as this meeting will be more than worth while.

PROGRAM FOR SEMI-ANNUAL MEETING OF AMERICAN SOCIETY FOR STEEL TREATING, MOUNT ROYAL HOTEL, MONTREAL, FEBRUARY 16-17, 1928

WEDNESDAY, FEBRUARY 15

Committee Meetings

9:30 A. M.—Meeting of Officers and Board of Directors. Parlor B.
9:30 A. M.—Meeting of Recommended Practice Committee. Parlor F.
9:30 A. M.—Meeting of Publication Committee. Parlor A.
6:00 P. M.—Early Birds' Dinner. Special tables in Main Dining Room.
7:30 P. M.—Option of tobogganing or theater party. Special cards of admission for Toboggan Club may be had at Registration Desk.

THURSDAY, FEBRUARY 16

Morning Session—Piazza Room

9:00-10:00 A. M.—Registration—Piazza Room.

Technical Session

Prof. Alfred Stansfield, Chairman

10:00-10:40 A. M.—*A Development of the Structure of the Micro-Constituents of Metals*—R. G. Guthrie, Peoples Gas Light & Coke Co., Chicago.
10:40-11:20 A. M.—*Medium Carbon Pearlitic Manganese Steels*—Jerome Strauss, U. S. Navy Yard, Washington, D. C.
11:20-12:00 A. M.—*Steels for Case Nitrification*—A. B. Kinzel, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.

Afternoon Session—Piazza Room

R. M. Bird, Chairman

2:00- 2:40 P. M.—*The Manufacture of Stainless Steel Castings in the Various Industries*—V. T. Malcolm, Chapman Valve Mfg. Co., Indian Orchard, Mass., and V. O. Homerberg, Massachusetts Institute of Technology, Cambridge.
2:40- 3:20 P. M.—*X-Rays and the Constituents of Stainless Steel*—E. C. Bain, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.
3:20- 4:00 P. M.—*Hardness Testing*—H. M. German, Universal Steel Co., Bridgeville, Pa.
6:30 P. M.—Dinner. Special tables in Main Dining Room. Technical Session following.

Evening Session—Piazza Room

President F. G. Hughes, Chairman

8:00- 8:45 P. M.—*Heat Treatment of Forgings and Castings for Selective Directional Adjustment of Residual Stresses*—W. J. Merten, Westinghouse Electric and Manufacturing Co., East Pittsburgh.

8:45- 9:30 P. M.—*The Modern Trend of Metallurgy*—Dr. F. C. Langenberg, Climax Molybdenum Co., New York City.

FRIDAY, FEBRUARY 17

Morning Session—Piazza Room

A. H. d'Arcambal, Chairman

9:30-10:10 A. M.—*Effects of Antimony, Arsenic, Copper and Tin in High Speed Tool Steel*—H. J. French and T. G. Digges, Bureau of Standards, Washington, D. C.

10:10-10:50 A. M.—*Some General Thoughts on Fusion Welding*—S. W. Miller, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.

10:50-11:25 A. M.—*Types of Failure of Steel*—Robert Job, Milton Hersey Co., Ltd., Montreal.

11:25-12:00 A. M.—*Some Failures of Locomotive Parts and an Examination of their Structures under the Microscope*—F. H. Williams, Canadian National Railways, Montreal.

Afternoon Session

1:30 P. M.—Choice of Plant Inspection:

(1) Canadian Steel Foundries, Ltd., Longe Pointe Plant, manufacturing locomotive frames, railroad castings and hydroelectric castings; and Canadian Vickers, Ltd., the largest Canadian producers of airplanes.

(2) Dominion Engineering Works, Ltd., and Dominion Bridge Co., Ltd., manufacturing largest paper machinery on this continent; also oil stills, tank work and heavy construction work.

6:30 P. M.—Dinner. Special tables in Main Dining Room. Technical Session following.

Evening Session

Nightingale Room—Main Floor

E. F. Cone, Chairman

8:00- 8:40 P. M.—*Alloy Steel for Boiler Construction*—Charles McKnight, International Nickel Co., New York City.

8:40- 9:20 P. M.—*The Effect of Heat Treatment on the Properties of Chromium-Molybdenum Sheet Steel*—F. T. Sisco and D. M. Warner, Wright Field, Dayton, Ohio.

9:20-10:00 P. M.—*A Note on the Hardness and Impact Resistance of Chromium-Nickel Steel*—B. F. Shepherd, Ingersoll-Rand Co., Phillipsburg, N. J.

SATURDAY, FEBRUARY 18

Afternoon—Province of Quebec Champion Ski Jumping by Montreal Ski Club at the Cote des Neiges Hill.

Evening —Professional hockey game between Detroit and Montreal Maroons.

News of the Chapters

SCHEDULED MEETING NIGHTS OF CHAPTERS

For the convenience of visiting members, those chapters having scheduled meeting nights are listed below.

BOSTON—First Friday, H. E. Handy, secy., Saco-Lowell Shops, Lowell, Mass. Phone, Lowell 4050.

Feb. 3—Methods of Constructing the Alloy Diagrams........R. S. Williams
Mar. 2—Hardening and Tempering of Steels..............R. S. Williams
Apr. 6—Pyrometry ....V. O. Homerberg
May 4—Stainless Iron and Stainless Steel..............V. O. Homerberg

BUFFALO—Fourth Friday. F. L. Weaver, secy., American Radiator Co., Bond Plant. Phone, Riverside 1770.

CANTON-MASSILLON—No schedule of meetings as yet received. Robt. Sergeson, secy., Central Alloy Steel Corp., Canton, Ohio. Phone 5121.

CASE GROUP—No schedule of meetings as yet received. J. M. Burns, secy., Case School of Applied Science, Cleveland. Phone, Garfield 6680.

CHICAGO—Second Thursday, with exception of March 6. J. A. Comstock, secy., Room 1724 Peoples Gas Bldg. Phone, Wabash 6000, Local 364.

Feb. 9—Pyrometry and Its Application.....................G. S. Gordon
Mar. 6—Nickel Cast Iron ....P. D. Merica
Apr. 12—Manufacture of Cold Drawn Steel ....F. R. Bonte

CINCINNATI—No schedule of meetings as yet received. W. J. Lange, secy., Robert J. Anderson, Inc.

CLEVELAND—Third Friday. J. S. Ayling, secy., Case Hardening Service Co. Phone, Atlantic 0293.

Feb. 17—Cap Screws ....Tom Ferry
Mar. 16—Brass and Bronze Alloy ....C. H. Bierbaum
Apr. 20—Metal Stamping ....G. L. Kelley
May 18—Social Meeting.

COLUMBUS—Third Tuesday, with exception of Feb. 14. G. D. Moessner, secy., Buckeye Steel Castings Co. Phone, Garfield 0600.

Feb. 14—Fuels and Furnaces ....H. J. N. Voltmann
Mar. 20—High Speed Steels ....J. V. Emmons
Apr. 17—Forgings ....Harold Wood
May 15—Open-Hearth Practice ....W. R. Flemming

DAYTON—No schedule of meetings as yet received. F. M. Reiter, secy., Dayton Power & Light Co.

DETROIT—Third Monday. Jos. G. Gagnon, secy., Hudson Motor Car Co. Phone, Lenox 3232.

FORT WAYNE—Paul Renfrew, secy., S. F. Bowser & Co. Phone, Harrison 2341.

Feb. —Procedure of Correct Hardening ....Jordan Korp
Mar. —Carburizing and Heat Treatment................B. F. Shepherd
Apr. —Nickel-Chromium Alloy in Gray Iron ....D. M. Houston
May —Shop Equipment and Shop Kinks ....H. B. Northrup

GOLDEN GATE—Second Wednesday. S. R. Thurston, secy., Bethlehem Shipbuilding Corp., San Francisco.

Feb. 8—Stanford University Visit
The Relation Between Cutting Power of Metals and Their Heat Treatment ....A. B. Domonoske
History of the Development of the Use of Metals....T. J. Hoover

Mar. 14—Symposium and Discussion by Members on the Physical Properties of Steel. Their Significance and Their Relations. Bases for the Selection of Carbon and Alloy Structural Steels for Specific Purposes.

Apr. 11—Joint Meeting with the American Welding Society—Subjects: Properties of Welds at High Temperature..........K. V. Laird
Properties of Carbon and Alloy Steels at High Temperatures.
May 9—The Hardness of Metals, Methods of Testing and What They Test. Comparison of the Wear Resistance of Different Metals Under Different Conditions of Heat Treatment.
June 13—Heat Treatments of Nonferrous Alloys, Their Purpose and Their Significance.
Moving Picture—The Story of Copper.

HARTFORD—Second Tuesday. Henry I. Moore, secy., Firth Sterling Steel Co. Phone, 6-5554 Hartford.

Feb. 14—Ask Me Another—Speakers, Anyone with a Question.
Mar. 13—Heat Treatment of Aluminum Alloys ....R. S. Archer
Apr. 10—Manufacture of Automotive Alloy Steels ....E. C. Smith
May 8—Manufacture of Malleable Iron..................H. A. Schwartz
June 8—Eighth Annual Banquet.

INDIANAPOLIS—Second Monday. James S. Marlowe, secy., 606 State Life Bldg. Phone, Riley 3724.

LEHIGH VALLEY—No schedule of meetings as yet received. H. V. Apgar, secy., Ingersoll-Rand Co., Phillipsburg, N. J. Phone 977.

LOS ANGELES—Second Thursday. H. V. Ruth, secy., Ducommun Corp. Phone, TR. 0621.

MILWAUKEE—Second Monday. Knight Charlton, secy., Bucyrus Co. Phone 1.

MONTREAL—No schedule of meetings as yet received. D. G. MacInnes, secy., Apt. 35, 376 Claremont Ave., Westmount, Montreal.

NEW HAVEN—Second Thursday, with the exception of June 15. F. E. Stockwell, secy., Standard Oil Co. of New York. Phone, Beacon 1520, Pioneer 9940.

Feb. 9—Dimensional Changes in Heat Treatment of Steel, Stanley P. Rockwell
Mar. 8—Manufacture, Use and Heat Treatment of Stainless Steel.... ....C. E. MacQuigg
Apr. 12—High Speed Steel ....J. P. Gill
May 10—Place of Nonferrous Metals in Industry.................. ....W. G. Price and Alvan L. Davis
June —Annual Frolic—Details and date will be announced later.

NEW YORK—Second Monday. I. N. Holden, Jr., secy., E. W. Bliss Co. Phone, Sunset 9000.

NORTH-WEST—No schedule of meetings as yet received. Alexis Caswell, secy., Manufacturers' Assn. of Minneapolis.

Feb. —Nitralloy ....R. P. DeVries
Mar. —Open
Apr. —Molybdenum Steels ....Dr. F. C. Langenberg
May —Gears and Gear Steel ....E. C. Smith

NOTRE DAME—Second Friday. Frank J. Mootz, secy., Notre Dame University. Phone, Lincoln 1121.

PHILADELPHIA—Last Friday. A. W. F. Green, secy., 407 Shoemaker Rd., Elkins Park, Pa. Phone, Melrose 4542-M.

Feb. 24—Nonferrous Metallurgy
Mar. 30—Case Hardenings with Particular Attention to Nitrogenizing
Apr. 27—General Melting Practice, Influence of Crystallization and Cooling on the Commercial Application of Metals.

PITTSBURGH—First Thursday. H. L. Walker, secy. Box 521, North Side Station.

RHODE ISLAND—Third Wednesday. C. G. Peterson, secy., 100 Weybosset St., Providence. Phone, Gaspee 6233.

ROCHESTER—Second Monday. Irving C. Mathews, secy., Eastman Kodak Co. Phone, Glenwood 1300.

Feb. 13—Testing ....T. Y. Olsen
Mar. 12—Dr. Jekyll and Mr. Hyde of Metallurgy..............T. S. Fuller
Apr. 9—Die Castings ....Sam Tour
May 14—Business Meeting—Election of Officers

ROCKFORD—Second Friday. O. T. Muehlemeyer, secy., 700-702 Race St. Phone, Forest 447.

SCHENECTADY—Third Tuesday. J. G. Hicks, secy., American Locomotive Co. Phone, 2-4900-Ext 44.

Feb. 21—Machinability and Machining Problems of Nickel Steels and Ordinary Cast Iron, Monel Metal, etc............T. H. Wickenden
Mar. 20—Steels at Elevated Temperatures..........H. J. French, F. B. Foley

SOUTHERN TIER—Third Monday, with exception of Apr. 23. Walter H. Odgen, secy., 11 Rotary Ave., Binghamton, N. Y. Phone, Bingham 2425.

SPRINGFIELD—Third Monday, with exception of Mar. 21, Apr. 25 and May 23. E. L. Woods, secy., Springfield Gas Light Co. Phone, 5-3900.

ST. LOUIS—Third Friday. C. C. Werscheid, secy., Colonial Steel Co. Phone, Garfield 1263.

SYRACUSE—Second Tuesday. S. P. Peskowitz, secy., Halcomb Steel Co. Phone, 3-1231.

Feb. 14—Some Phases of the Iron and Steel Industries..........W. W. Macon
Mar. 13—Carburizing and Heat Treatment of Carburized Objects...B. F. Shepherd
Apr. 10—Flow of Metals in Forging ....J. H. Nelson

TORONTO—No schedule of meetings as yet received. A. Lowry, secy., 450 Willard Ave.

TRI CITY—No schedule of meetings as yet received. George A. Uhlmeyer, secy., People's Power Co., Moline, Ill.

WASHINGTON-BALTIMORE—No schedule of meetings as yet received. H. K. Herschman, secy., Bureau of Standards.

WORCESTER—Feb. 3 and Mar. 14—no further meeting dates as yet scheduled. C. G. Johnson, secy., Worcester Polytechnic Institute. Phone, P110.

STANDING OF THE CHAPTERS

DURING the month of December there were 117 new and reinstated members, while 146 were lost through arrears, resignations and deaths, leaving a net loss for the month of 29 members. The total membership of the Society on January 1, 1928, was 4832.

Membership standing of the society as of January 1, 1928, is as follows:

GROUP I		GROUP II		GROUP III	
1. Detroit	491	1. Dayton	133	1. Los Angeles	95
2. Chicago	432	2. Hartford	127	2. Tri City	91
3. Pittsburgh	360	3. Milwaukee	121	3. New Haven	82
4. Philadelphia	330	4. Lehigh Valley	117	4. Worcester	73
5. Cleveland	310	5. Golden Gate	116	5. Washington	71
6. New York	299	6. Canton-Mass.	110	6. Rockford	63
7. Boston	257	7. Indianapolis	100	7. Rochester	59
		8. Cincinnati	92	8. Columbus	57
		9. St. Louis	92	9. Toronto	55
		10. Syracuse	88	10. Providence	54
		11. Montreal	72	11. Southern Tier	51
		12. Buffalo	68	12. Fort Wayne	41
		13. North-West	49	13. Schenectady	41
				14. Springfield	34
				15. Notre Dame	26

GROUP I—Detroit suffered the heaviest loss (12) by arrears and resignations, though they still retain position No. 1. Pittsburgh made fine progress this month by gaining 10 new members. New York and Boston showed slight gains while Philadelphia and Cleveland lost 5 and 1 respectively.

GROUP II—The chapters in this group all keep the same positions as on the last report, five suffering losses, four gaining slightly and four having the same number as reported last month.

GROUP III—Los Angeles takes the lead in the third group, while Tri City drops into second position, though having a slight gain. Southern Tier losing 10 members drops from 8th to 11th place, bringing Columbus, Toronto and Providence each one position higher than last month.

BOSTON CHAPTER

The January meeting of the Boston chapter was devoted entirely to physical testing of materials, two of the best known authorities on this subject appearing on the program. The first speaker, Prof. Irving Cowdrey, associate professor of testing materials at Massachusetts Institute of Technology, and a former chairman of the Boston chapter, illustrated very clearly the principles of the common testing machines and explained the difference between static and dynamic loading. He also described the verification of testing machines, explaining the older methods and exhibiting the "Brinell Proving Ring" and the "Amsler Calibration Box."

The guest speaker of the evening was Dr. Frederick C. Langenberg, Vice President of the Climax Molybdenum Company, New York. Dr. Langenberg, formerly of the Watertown Arsenal and for several years a member of the Boston Chapter, was enthusiastically received and gave a very interesting talk entitled "The Meaning and Value of Impact Testing." He presented a number of slides showing the effect of high and low temperatures on the impact value of the notched bar. The moving parts of locomotives, automobiles and airplanes are in reality notched bars. In our New England climate they are subjected to the particular range of temperatures in which the extremes of high and low impact values appear, namely 30 degrees below to some 100 or more degrees above zero. To prevent excessive failures of these parts, Dr. Langenberg emphasized the importance of careful study of the steels used, and their heat treatment, so that the impact value will be sufficient and as uniform as possible throughout the ordinary temperature range.

The usual dinner, presided over by Chairman Leslie D. Hawkridge, was held in Walker Memorial at 6:15 p. m., about seventy members attending.

H. E. Handy.

The Boston Chapter Educational Course

Ninth Lecture.—"Ingot Phenomena" and "Forging, Pressing and Rolling of Steel" were the subjects discussed by Dr. G. B. Waterhouse in the 9th lecture of the Boston Chapter Metallurgical Course on Friday, December

9, 1927. Bottom and top methods of pouring ingots were described and the advantages of each given, with also a description of some of the methods used to obviate the "splash" when top pouring is employed. Speaking of ingot phenomena, the elimination of the pipe and surface blowholes, as well as methods used to decrease segregation, were discussed.

After describing early methods of shaping iron and steel, Dr. Waterhouse showed a series of slides picturing modern rolls, steam hammers, hydraulic presses and forging machines. Cold working was briefly touched, examples being the manufacture of cold drawn screw stock and wire products.

Tenth Lecture.—The 10th and last lecture by Dr. Waterhouse was given on December 16, 1927, his subject being "A Brief Description of the Principal Alloy Steels." Pointing out that the main effect of the various alloying elements is to emphasize some special property such as hardness or toughness; resistance to shock, fatigue, corrosion, etc., and that as a general rule the full value of the various alloys is not brought out until they have been subjected to careful heat treatment, the speaker proceeded to describe the commonly used alloy structural steels. He also touched briefly on manganese castings, silicon sheet and high speed tool steel.

Eleventh Lecture.—After a two weeks vacation the second section of the Educational Course began on Friday, January 6, 1928, with Irving H. Cowdrey, associate professor of testing materials at M. I. T., and a former chairman of the Boston Chapter, on the platform. Prof. Cowdrey first discussed the tensile test machine explaining the correct gripping of the specimen, the mechanical means for moving one of the gripper heads and the means of weighing the load applied. Machines for compression, torsion and bending were also taken up under the heading of "static loading." After explaining the difference between "static" and "dynamic" loading, the machines and test pieces for the Izod, Charpy and Stanton tests were described.

The speaker, while admitting that some of the foreign made machines for testing materials were, no doubt, very accurate and reliable, stated that in his opinion the machines made by the two manufacturers of testing apparatus in this country filled all the requirements necessary for testing the physical qualities of materials. *H. E. Handy.*

BUFFALO CHAPTER

At the Hotel Statler on December 15, 1927, a meeting of the Buffalo chapter was held. The meeting was called to order by chairman McCarthy at 8:30 p. m.

The first speaker, G. F. Anderson of the Niagara Lockport & Ontario Power Co., enlightened those present with an interesting talk on the geological and commercial history as well as the future power possibilities of our Niagara Falls.

The principal speaker, C. H. Bierbaum, vice-pres. of the Lumen Bearing Co., Buffalo, is an authority on nonferrous metallurgy and bearing metals, his talk and lantern slides showed the remarkable effect of the heat

treatment of these alloys. His experimental data is of great value to metallurgists in general as shown by the very interesting discussion that followed.

After adjournment, a buffet lunch was served to about fifty members and guests. *F. L. Weaver.*

CLEVELAND CHAPTER

The regular meeting of Cleveland Chapter A. S. S. T. was held Friday evening, December 16, 1927, at the Cleveland Engineering Society Rooms, Carnegie Hall.

The speaker, H. A. DeFries of the Ludlum Steel Company, delivered a very interesting talk on Nitralloy, its treatment and the method of case hardening with nitrogen.

The points stressed were the importance of temperature control, both in preliminary treatment to obtain the physical properties desired and in the temperature of nitriding. The selection of the proper alloy and depth of case call for careful study of the requirements to be met.

All work is finished before nitriding, although there is usually present a film after being nitrided which is best removed to obtain maximum hardness which is considerably above that of the ordinary carburized work.

The nitriding is accomplished by supporting the work in a closed retort heated in an electric furnace with accurate control and passing ammonia gas free from moisture and impurities through this chamber. The temperature used ranges from 850 to 925 degrees Fahr. and the time varies from 12 to 90 hours depending on the penetration wanted.

The talk was very well received and numerous questions and answers followed.

Our National Secretary, Bill Eisenman, was welcomed at the meeting with a round of applause and after making a few remarks Bill, with the aid of his able assistant, Ray Bayless, showed some films taken at the National Office and at the Detroit Convention. Mr. Eisenman has promised to show the films which he took while abroad at a meeting in the near future.

The question box was started under the direction of C. G. Shontz. All questions which members desire answered will be answered in order received at future meetings as rapidly as possible.

This meeting was well attended, about 150 members and guests being present. About 35 were present at the dinner. *J. S. Ayling.*

DAYTON CHAPTER

On December 19, the Dayton Chapter and the Engineer's Club of Dayton met jointly at the Engineer's Club to hear C. F. Kettering, honorary member of the society and president of the General Motors Research Corporation, give a "Scientific Review" of research progress for the past year. In his own characteristic and inimitable manner Mr. Kettering spoke for nearly two hours on research progress, both within his own field and in the world at large. He touched on a wide variety of subjects; synthetic rubber, paints, steel inspection problems, anti-knock gasolines and motor fuels and many others.

Among the more interesting things he told the audience were the possibilities of increasing the efficiency of internal combustion engines by a more accurate knowledge of the composition of gasoline and described a new fractionating still now being perfected which will permit of an accurate separation of gasoline into its various component compounds. Mr. Kettering predicted that should the need arise we would soon be growing our gasoline. Starch can now be synthesized from gasoline, hence it would be a comparatively simple problem to reverse the process.

Mr. Kettering described in detail and with much humor the last European exhibitions of motor cars. He reminded his hearers of the present European influence on American body design and told of tracing this influence to a couple of young American body makers in Paris.

Mr. Kettering's talk was enjoyed very much by all of the Dayton Steel Treaters who attended. *F. T. Sisco.*

DETROIT CHAPTER

The Detroit Chapter of the American Society for Steel Treating held its December meeting the 19 at 6:30 in the General Motors Bldg. The coffee talk was dispensed with and musical entertainment provided.

At 8:30 Mr. Blackwood of the Buick Motor Company presented a paper on the metallurgical aspects of "Cast Iron". Mr. Blackwood's masterly paper cannot in justice be reduced to general terms. In it he stated that within very wide limits the character of a casting, particularly its solidity, freedom from defects, and general appearance, is influenced in a minor degree by ultimate composition. The mode of existence and the manner in which the components are distributed has a greater influence upon the porperties than the actual quantities of the elements present. This is due to two principal causes: (1) A substance may separate and have an independent existence, and the effect produced will depend upon when the separation occurs,—that is, before, during or after solidification. If separation is effected before solidification, the substance has freedom to take a position in accordance with the relative specific gravity; if during solidification freedom is restricted, there is no chance of complete elimination, and it will become entangled in meshes of the solidifying mass, or migrate in the direction of the still liquid portion. A substance which separates after complete solidification remains intimately associated with the mass; its ultimate distribution depends on the degree of liberty of the particles, and the degree of independent existence it attains will be to a large extent governed by its diffusibility. (2) The substance may remain in solution, and thus have a direct action on the metal, and so modify its properties,—that is, its tenacity, hardness, et cetera. It may also alter the behavior of the other bodies present. The better grade of irons are the pearlite cast irons. The essential facts in producing these irons are: first, the graphite must be reduced in quantity and in size of flakes; second, the phosphorus must be reduced to practically negligible limits, as it induces weakness in the pearlite; and third, the silicon content must be so adjusted that the combined carbon in the finished casting is not excessive for the thickness of the metal being cast. The percentage of combined carbon, however, may vary between fairly wide limits, and pearlitic irons have been made with 0.55 to 0.89 per cent of

combined carbon. A specimen of metal having a combined carbon of 0.56 per cent exhibited under the microscope an all-pearlitic structure at the high magnification of 600. Additionally, slow cooling in the mold is essential to avoid chilling the job. Hence, the desirability of a hot mold, but this again is a function of the weight of metal to the weight of molding sand, and not in itself a special factor, but only a relative one.

Mr. Blackwood also took up the effect of alloy elements on cast iron, but believes a good pearlite iron will answer the needs of modern design.

At the conclusion of his paper Mr. Blackwood was given a rising vote of thanks and the meeting was turned over to an informal Christmas get-together.

J. G. Gagnon.

DETROIT CHAPTER—ANN ARBOR GROUP

On Thursday evening December 1, thirty-eight members and friends gathered in room 3201 East Engineering Building, Ann Arbor, Michigan, to renew the activities of this division of the Detroit Chapter. The weather was rather inclement so that none of our friends from Detroit were able to be with us, although we knew they were hoping that we would have a successful meeting.

Professor A. E. White was the speaker of the evening and spent the time in a review of the impressions received during his recent trip to Europe. His first stop was in Great Britain where he described a visit to the plant manufacturing the Austin car, one of the typical low powered cars of Europe. He stated that the Essex was the American car most frequently seen and also that most every owner of an Essex had a chauffeur. Interviews with F. W. Harbord, Harry Brearley, and W. H. Hatfield, prominent British metallurgists were described.

Journeying over to the continent of Europe Professor White attended the International Congress for Pure and Applied Chemistry at Warsaw and the International Congress for Testing Materials at Amsterdam where he delivered a paper. At these gatherings he met many internationally known scientists.

Later visits were made to Italy, Switzerland and France where his various experiences and observations were interestingly told. He is strongly of the opinion that another war in Europe is only a question of time, as there are many sore spots. One of these is the result of the rather peculiar condition where an arm of Poland completely separates east Germany from the rest of Germany.

After Professor White's talk, sandwiches, coffee and smokes were provided and the group spent a pleasant hour in chatting together on a variety of subjects.

FORT WAYNE GROUP

The December monthly meeting of the Fort Wayne group was held on December 14, in the Y. M. C. A. Banquet Room. Dinner was served at 6:30 p. m. to an attendance of 37. During the dinner music was furnished by the Bowser Male Quartet.

The speaker of the evening, Owen K. Parmiter, metallurgist of the Firth-

Sterling Steel Company, was introduced immediately after dinner by our chairman, W. E. McGahey.

Mr. Parmiter's subject was "New High Chromium Steels," which included the full group of stainless steels, and touched to some extent upon the tool and high speed steels. He read a most interesting paper on this subject, covering such points as the analysis of the various steels in this group, the correct forging and heat treating temperatures, etc. He also gave us considerable information concerning the application of the various stainless steels.

Mr. Parmiter's paper was followed by a discussion, which was entered into by a goodly portion of the members present.

In spite of the fact that the attendance was considerably smaller than that enjoyed by this chapter in the previous meetings, this was one of the most interesting and beneficial meetings held by this group to date.

P. B. Renfrew.

GOLDEN GATE CHAPTER

Golden Gate Chapter held its annual smoker Saturday, December 12 at the Engineer's Club, San Franciso. In the spacious dining room a most excellent dinner was served. From time to time musical numbers punctuated this sumptuous repast.

Through the courtesy of the Midvale Co. Pete and his stringed ¼ gallonette made the evening more enjoyable by their dulcet harmonies. Due to the efforts of F. L. Wright of the U. S. Steel Products, Dick Read entertained with several tenor solos—some of which were of a decided Scotch nature. Jesse of Ludlum and "K L X" sure did make that banjo sing and Professor Schitznel of the University of Cincinnapolis, gave his famous football broadcast and an intelligent dissertation on "Siestas in the Fullaprunes". The Professor was the guest of Bethlehem Steel and Earle M. Jorgenson Co. As a finale a skit "Christening of the Twins" was enacted by members of the local section. "Barney" as the Rabbi—Fred Wight as sky-pilot, Shorty as "mama" and Oliver P. as "papa" were quite in evidence. On account of the lateness of the hour, however, certain parts of the skit had to be cut short.

It is particularly to be regretted that after the untiring efforts of J. Vanadium Coulter and members of the entertainment committee, only fifty (50) members and guests came to the affair. *S. R. Thurston.*

HARTFORD CHAPTER

"Chromium Plating", a subject of great interest at present to all producers and users of metal goods, was described in a lecture by Dr. Wm. Blum of the Bureau of Standards, at the regular meeting of the Hartford Chapter which was held Tuesday, December 13 in the Hartford Electric Light Auditorium. Dr. Blum reviewed some of the history of chromium plating, described some the work at the Bureau, compared the strength of various plating baths by graphic charts which were projected on the screen from lantern slides. Dr. Blum delivered his talk in an engaging manner

which held the interest of his 225 listeners for an hour and a half which was followed by a discussion of about an hour that cleared up many details of chromium plating processes and applications. The fact that Dr. Blum apparently is a practical chromium plater as well as a scientific authority on the subject was pleasing to many who received several practical ideas on methods of obtaining good results with the process. This is another meeting of the Hartford Chapter that was a real, tangible value to its members and the Chapter wishes to make this a statement of appreciation of the work of Dr. Blum and his associates; of his visit in Hartford and the lecture which he delivered.

Preceding the talk on Chromium Plating, the second practical problem discussion was started by Carl Anderson, who is a foreman heat treater in the New Departure Mfg. Co. of Bristol, Ct. Mr. Anderson described the efforts of the metallurgical and heat treating departments to produce a grinding spindle for use in making ball bearings, which would have long life while operating with a reduced amount of oil film. The various types of steel selected have been given extended tests at an elevated temperature to determine which material retained its initial hardness or lost the least amount of hardness over the period. The discussion brought out a few heat treating questions and a great many more mechanical questions. There was a good example in this subject of the close relations that must be maintained between both the mechanical and metallurgical fields, if success in a problem is desired. It was a very good demonstration of the opportunity existing in the American Society for Steel Treating for both of these groups to work closely together. *R. Stanton.*

On Tuesday, January 10, the Hartford chapter held its regular monthly meeting in the Hartford Electric Light Auditorium. Gregory J. Comstock, research metallurgist of the Firth Sterling Steel Company of McKeesport, Pa., was the speaker. Mr. Comstock used for his subject "Recent Developments in Stainless Steels and their Applications." He brought out the point that not so much had been done in changing stainless steel itself as had been done in introducing many new applications of this material. As far as stainless steel itself is concerned only refinements have been made in its manufacture and treatment. He then described certain features of his recent visits to the cutlery shops in Sheffield, England. The discussion was centered around applications of stainless steel, questions about heat treatment, and resistance properties. There was some discussion regarding stainless steel and the influence of chromium plating. Mr. Comstock's paper was very well written and was delivered in an interesting manner. The Firth Sterling Steel Co., provided an interesting exhibit of recent products using stainless steel and stainless irons. The practical talk was given by David A. Nemser, metallurgist to the Machine Tool Works of Pratt & Whitney Company. Mr. Nemser described the "Results of Certain Physical Tests

on Medium Carbon Alloy Steels,'' which were made a short time ago. The results of these tests were illustrated with lantern slides.

The next meeting on February 14, will be the Annual Question Night. There will be no regular speaker. A list of questions will be prepared in advance for consideration before the discussion at the meeting.

R. Stanton.

INDIANAPOLIS CHAPTER

The December meeting of the Indianapolis Chapter was held in the Assembly Hall of the Diamond Chain & Manufacturing Company. This meeting was different than the usual meetings. We did not have any speakers and it is difficult to tell, which was the main feature of the evening, although we express our appreciation of the film, ''The Age of Speed'', loaned to us by the Norton Company of Worcester, Mass.

Preceding the showing of this film, we were entertained with music by the Link-Belt Company's string orchestra, also several classical numbers, both violin and vocal, by the Harmony Troubadors of the Marmon Motor Company, and this was followed by a black face skit, ''Heat Treated Comedy'', by Dave Killion, foreman of heat treat department and Arthur Jones, both of the Link-Belt Company.

To lend the collegiate flavor, the Diamond Chain Quartet sang a number of college songs.

One of the interesting features of the evening, was a bout, between two local pugs, who fought three fast rounds, which were refereed by Bud Fisher, our energetic treasurer, who decided the match was a draw.

After the program was completed a buffet lunch was served in the dining hall.

C. R. Ramage, purchasing agent of the Diamond Chain, welcomed us and extended to us the hospitality of his company.

Mr. Ramage was followed by Mr. Deoppers, superintendent of the Diamond Chain and also president of the Indianapolis Superintendents' and Foremen's Club. In closing Mr. Deoppers said, while the purchasing department bought the steel, the production department worked it up, but in the end the heat treating department proved that both the purchasing department and production department were wrong.

There were 135 present, including several guests and members from out of town.

James S. Marlowe.

LOS ANGELES CHAPTER

The December meeting of the Los Angeles Chapter was held at the usual place—The Los Angeles Creamery Company's Banquet Room at 6:30 p. m., December 8, which was an unusually interesting meeting. About seventy members sat down to a very good dinner, and to make the meal more enjoyable we were entertained with radio music due to the kindness of the Gilfillan Bros.

A report from Carl Fromme told of the activities of the Convention

Committee and the expectation of a convention in Los Angeles of the A. S. S. T. was received with much enthusiasm.

A very interesting talk was delivered by J. H. Kindelberger, chief engineer of the Douglas Aircraft Co. of Santa Monica, on the materials used in the construction of aircraft. The choice of materials depend upon the strength-weight factor, availability, suitability to fabrication, permanence, initial cost and correct use in design. Because of the extreme care in the choice of materials, the specifications for purchase must be very exacting and the Government specifications have done much to advance the art and provide better materials commercially available.

The various materials used in the manufacture of the plane were noted: Spruce and other woods were mentioned, and the extreme care that must be taken in the selection of wood was told and the point was brought out that as much as 50 to 75% of the selected stock must be thrown away at times due to hidden defects that show up in the machining operations.

The other materials were dwelt upon at considerable length, such as the aluminum alloys, the various steels with particular reference to chromium-molybdenum tubing, which is finding an important place in the building of the fuselage. The talk showed very clearly that the metals are slowly but surely replacing wood for all highly stressed members, due to its greater dependability.

Following the talk, Mr. Kindelberger answered a great many questions regarding details brought out in his talk, and during the discussion he called upon Mr. Leigh M. Griffith, formerly of the National Advisory Committee of Aeronautics, to aid him in giving information regarding questions asked regarding the materials used in engine design.

H. V. Ruth.

The January meeting of Los Angeles Chapter was held at Torrance, Calif., Friday evening, January 6. The dinner was served in the Women's Club, and the ladies of Torrance certainly gave the boys a real New Year's dinner. Dinner was served to one hundred and thirty members and guests.

Following the dinner our chairman, Wade Hampton, introduced the largest number of new members to the chapter, that has ever been announced in any one month in the history of the chapter. We are certainly glad to have so many new members, and hope that they will profit greatly through the Society, and we also hope that they will lend their efforts in securing other members from their associates and friends.

We were very fortunate in having with us, at this meeting, our good friend and national secretary, W. H. Eisenman. We wish that Cleveland were not so far from Los Angeles, so that we might have Bill with us frequently. Mr. Eisenman gave us a short talk which was very much enjoyed by the boys. He told us of some of the many things he had accomplished in our city during the few days he had been with us. He also told us of the many things that were to be done by our chapter to make certain the success of the Semi-Annual Metals Exposition and Convention

to be held here in 1929. He made us realize that our responsibility is great and that we all have much work to do.

We also had at this meeting, Dr. Welton J. Crook, chairman of Golden Gate Chapter. Dr. Crook delivered a short talk to the chapter, that we all enjoyed. We were very glad to have Dr. Crook with us and to have him meet the members. He told us that he was pleased that the Convention was coming to Los Angeles, and that Golden Gate Chapter would help us all they possibly could to make the Convention a great success. We hope that Dr. Crook will be able to meet with us often.

After the dinner we all went to the Torrance Plant of the Columbia Steel Co., and were shown through the many departments of the mill. Everyone enjoyed the trip greatly, and want to express to the management our deep thanks, and to especially thank our good member, Joe Cooke, for his work in making the trip and visitation such a pleasure and treat.

H. V. Ruth.

NORTHWEST CHAPTER

On Friday evening, December 16, the Northwest Chapter held its regular monthly meeting in the Builders Exchange Building, Minneapolis.

The program consisted of a four reel film, ''Age of Speed'', produced by the Norton Company of Worcester, Mass., supplemented by a talk by their sales engineer, H. K. Clark.

The picture proved very interesting, showing how the development of modern machines depends to a very great extent upon grinding, particularly precision grinding. The manufacture and application of grinding wheels was also very clearly shown.

Mr. Evans explained that modern production methods have called for many improvements in grinding equipment. As a result, certain pieces ground at a rate of 180 per hour one year ago are now being turned out at the rate of 600 per hour, and maintain even greater accuracy.

Each class of material demands grinding wheels of some particular specification in order to be ground properly in the minimum amount of time. The properties of grinding wheels may be listed as follows: abrasive used, grain size, structure, bonds, hardness, density.

By varying these properties wheels may be produced for nearly any class of work or condition. Aside from the proper selection of wheels, it is necessary that particular attention be paid to the speed of revolution, feed, and pressure in order that the best results may be obtained. *A. G. Zima.*

PITTSBURGH CHAPTER

Pittsburgh chapter held its January meeting on the evening of the 5th at the Bureau of Mines Building, Forbes St.

The meeting was preceded by dinner in the cafeteria after which a motion picture on copper was shown.

In the absence of chairman Gill, vice chairman McInerney presided.

The speaker of the evening was Jordan Korp of the Leeds & Northrup Co., and his subject was, ''Practical Heat Treating.''

His talk was very instructive and was listened to with great interest. Some valuable points were brought out in the after discussion.

H. L. Walker.

ROCHESTER CHAPTER

On Friday evening, December 9, the chapter held a special meeting preceded by the usual informal dinner at which 19 members and visitors were present. After the dinner all retired to the Assembly Hall and as there was no business for transaction, G. C. VanVechten, chairman, introduced Messrs. Russeau and Elya, representatives of the Norton Company. The former made a few preliminary remarks relating to the movie film which his Company had prepared, after which four very interesting reels entitled, "The Age of Speed" were shown.

The pictures were descriptive of the many wide and various uses of grinding wheels and abrasive, featuring the grinding of rubber, edge tools, pulp for newsprint, auto parts, farm machinery, etc. Not the less interesting were the processes of manufacture of the Norton Company of their complete line of products from the ore used to finished wheels and abrasives.

Following the showing of the picture a very lively discussion took place, Mr. Russeau answering all questions very satisfactorily. *H. J. LeClaire.*

The eighty-third meeting of the Chapter was held on Monday, December 12, at the Hotel Osburn. Dinner before the meeting was served to thirty members and visitors. After the dinner all retired to the Assembly Hall and our Chairman, G. C. VanVechten, introduced the speaker, Dr. G. L. Kelley of the Edward G. Budd Manufacturing Co. of Philadelphia. Dr. Kelley's subject was "Sheet Steel Stampings", followed by motion pictures showing the plant of the Edward G. Budd Co. and the manufacture of automobile bodies. The pictures showed different stages of the body being formed and welded and were most interesting. Discussion followed the meeting.

H. J. LeClaire.

ROCKFORD CHAPTER

The third regular meeting of the Rockford Chapter was held Friday, December 9, in the Venetian Room of the Nelson Hotel. Fifty-five members were present at the informal dinner which preceded the meeting.

Vice-Chairman R. M. Smith presided at the business meeting, which was opened at 8 p. m. Chas. Cotta, chairman of the membership committee, explained the change in membership classification adopted at Detroit, and distributed the new membership applications. R. M. Smith discussed the formation of a technical papers sub-committee from the Rockford chapter.

At 8:15 the meeting was turned over to the speaker of the evening, H. K. Clark of the Norton Company. Mr. Clark first showed a four reel moving picture illustrating why this is called the "Age of Speed". It brought out the part played by grinding wheels and machines in the development of speed. In his talk which followed, Mr. Clark explained the close

contact that abrasive engineers maintain with developments made by steel treaters.

Mr. Clark also showed a number of specimens that illustrated proper and improper grinding. Some interesting discussion followed in which a number of questions and problems were answered by the speaker. A rising vote of thanks was extended to Mr. Clark and the meeting adjourned at 10:15 p. m.

H. W. Gustafson.

The fourth regular meeting of the Rockford chapter of Steel Treaters was held Friday evening, January 13th, at 8 p. m. in the Venetian Room at the Nelson Hotel. Preceding the meeting an informal dinner was served to 72 members and guests.

Due to the fact that there were two speakers on the program, the usual business meeting was dispensed with. In introducing the speakers, O. T. Muehlemeyer explained that the American Society for Steel Treating had broadened its field to include more than just steel and its treatment; that it now included work on cast iron and nonferrous metals. He then announced that the papers to be given would deal with the subject of cast iron.

The first speaker of the evening was George W. Zabel, metallurgist, Fairbanks, Morse & Company, Beloit, Wisconsin. The title of his paper was "Some Data on High Test Iron." He spoke of high test irons as compared to semi-steel and ordinary gray iron. He related his experience in making high test iron in a continuous-run cupola furnace, and the results he has obtained. He showed some very interesting photomicrographs and test pieces that illustrated the various points he brought out in his talk.

The second speaker was Duncan P. Forbes of the Rockford Malleable Iron Works, who spoke on "Air Furnace Products." Mr. Forbes first gave the construction and operation of air furnaces as compared to cupola furnaces. He spoke of the better product obtainable in the air furnace due to the fact that the melt does not come in contact with the fuel as in the cupola, and that a higher heat is obtained in the air furnace. He talked on their new product "Gunnite," a high strength iron that can be heat treated to a Brinell of 477 to 500.

Much interesting discussion followed the presentation of these two papers and the meeting adjourned, with a rising vote of thanks to the speakers, at 10:00 p. m.

H. W. Gustafson.

SPRINGFIELD CHAPTER

The monthly meeting of the Springfield Chapter was held on December 19 at the Springfield Chamber of Commerce preceded by the usual dinner at the Highland Hotel.

After a short business session the chairman, John W. Juppenlatz, introduced the speaker of the evening, J. R. Dawson of the Union Carbide and Carbon Research Laboratories Inc., who presented a talk on "Some Phases of Oxyacetylene Welding." In order that this talk might be of some practical benefit to everyone present, a number of subjects were discussed including

principles of welding, weld testing, arc welding, atomic hydrogen welding, heat treatment of welds, welding cast iron, alloy steels and oxyacetylene cutting.

Mr. Dawson stressed the importance of making tests on welds and advocated the bend test as one of the best methods of investigation. Several interesting lantern slides were shown giving data supplementing this. He described a weld as an engineering proposition and said before undertaking it the welder should consider it as such; laying out his work beforehand, selecting the proper materials, and giving careful attention to the proper technique.

Information regarding the welding of stainless and chromium irons which are now coming into general use was received with much interest. It seems that the greatest degree of success is obtained with this class of material when chromium steel welding wires having about eight per cent of nickel are used.

Apropos of atomic hydrogen welding, Mr. Dawson said that the chief difficulty encountered is the inclusion of hydrogen in the welds, but this factor does not enter into the welding of thin sheets.

It seems that among a certain group of engineers the impression exists that cutting with the oxyacetylene flame has a harmful effect on the physical properties of steel, but the results of tests were shown which proved that this was untrue.

Active discussion ensued considering these points and others that the speaker touched upon during the evening.

T. P. Jones.

ST. LOUIS CHAPTER

The 71st regular monthly meeting of the St. Louis Chapter of the A. S. S. T. was held Friday evening, December 16, 1927, at the American Annex Hotel. The meeting was preceded by the usual dinner, with about 60 members and guests enjoying the dinner and pre-Xmas entertainment. We know this entertainment was enjoyed by the repartee and general good fellowship that was carried on across the festive board.

After a short business session James P. Gill of the Vanadium Alloy Steel Company was introduced, who discoursed on high speed steel. Mr. Gill's talk was illustrated with lantern slides and two reels of motion pictures, showing the manufacture of high speed steel. He talked on development, composition, structure and treatment in language that was understood by all and I am sure the members and guests who attended one of our most successful meetings spent a most enjoyable and educational evening. The writer wants to say that he enjoyed Dr. Gill's discourse and we are sure the St. Louis Chapter will be willing to talk in the language of the country editor, "come back again, Jimmy."

The meeting was adjourned, with a vote of thanks to Mr. Gill and his Company, until the New Year at which time Dr. N. B. Hoffman of the Colonial Steel Company will give us a talk on tool steels and shop kinks.

C. G. Werscheid.

SYRACUSE CHAPTER

The third meeting of the Syracuse Chapter was held on December 13 in the Chamber of Commerce Building. This well attended meeting was opened with the regular routine business, following which, J. B. Johnson of McCook Field was introduced as the speaker of the evening. Mr. Johnson had with him a splendid exhibit of airplane parts and also a most comprehensive set of lantern slides to illustrate his talk.

The designs in engines, wings, controls and propellers have all changed and improved with time. "It was not until after the war that metal framing was successfully used in airplanes. The first framing had been bamboo, lashed at the joints, and braced with piano wire." "Contemporaneous with the introduction of aluminum alloy framing in Germany, Fokker in Holland produced his machines with welded steel tubing. The Germans used the now well known duralumin, in sheets, shapes, and tubing, but on account of the still present difficulties in, and objections to welds in this material, the joints were riveted. Fokker used low carbon seamless steel tubing, with fishtail joints securely welded."

"The government has favored the use of steel tubing and by tightening up on specifications, the physical properties have been increased from a 50,000 pounds per square inch average to over 90,000 pounds per square inch. In addition to straight carbon, alloys of 3½ per cent nickel, 5 per cent nickel, chromium-vanadium and chromium-molybdenum have all been successfully used. The latter, when of the composition, 0.25-0.35 carbon, 0.80-1.10 chromium, 0.15-0.30 molybdenum, has been found to be more satisfactory than the others, for the welds will air harden some, and the tensile strength then will be well over 80,000 pounds per square inch. Larger and intricate parts that are best made with tubes, sheet and welds in combination may be heat treated before they are placed in the framing, thus increasing the physical properties, and allowing an important saving in weight."

Mr. Johnson then resorted to his exhibits explaining the intricate welds used in engine supports and in landing gears. In one case a piece had twelve joints practically in one junction, necessitating 125 feet of welds. The welds on this piece were perfect, and Mr. Johnson added that with average care taken in making the welds, no trouble is experienced in getting good joints. The different types of wing ribs were shown us with the riveted tubing, the veneered wood and the extruded beam classes of cantilever supports. Doped fabric is still found to be the most satisfactory covering.

H. Lyon Day.

WASHINGTON-BALTIMORE CHAPTER

On November 29, the Washington-Baltimore Chapter which met at the Engineers Club in Baltimore had a most successful meeting in the form of a banquet and technical meeting.

After the banquet, Chairman Gathmann called upon Mr. Jerome Strauss, metallurgist of the U. S. Naval Gun Factory, to give his 'surprise act'.

Mr. Strauss had chosen ten broken tensile test bars of the rarest varieties of steels and submitted them to those present for the purpose of having open competition for the determination of the types or names of steels by fractures. In order to lessen the burdens for the competitors, Mr. Strauss furnished among other machine shop equipment, a grinding wheel for spark tests. The results reported by the examiners of the answers returned showed Mr. French of the Bureau of Standards to be the most learned of the 'fracture artists' present with Mr. Mull of the Rustless Iron Company a close runner-up. These gentlemen were awarded prizes in the form of text books.

The 'banner-features' of the evening which included talks by R. M. Bird, past president of the society and E. C. Smith, assistant general superintendent of the Central Alloys Steel Corporation, followed next. It is needless to say that Mr. Bird, who spoke on the value of the society to individuals as well as to industrial organizations, put this across in such excellent fashion.

The balance of the evening was given over to the technical meeting, the speaker being E. C. Smith, who gave an unusually interesting talk on alloy steels with much specific data, particularly in regard to applications which it is impossible to include in a brief abstract.

The nickel steels were discussed in detail, followed by a discussion of the effect of additions of chromium to the nickel steel series. The advantages of the high-nickel chromium steels for intricate or large sections to be heat treated were emphasized. The addition of vanadium to the nickel-chromium steel was said to broaden the quenching range and was advantageous in the carburizing steels.

Mr. Smith stated that he believed molybdenum had not yet located its natural field. The various combinations of molybdenum with other alloying elements were discussed.

The chromium steels as a class were considered in detail and stated to be the only complete series of alloy steels being used from the carburizing to the ball steel grades.

The importance of the physical metallurgy as compared to the chemistry of steels was emphasized and the necessity of selecting the steel to meet the manufacturing operations as well as the ultimate use. Particular emphasis was made on the type of heat treating furnaces that should be used.

The discussion was lively and long, touching all phases but had particular reference to the relative value and difficulties of heat treating in salt bath and lead bath versus electric heating.

The December meeting was held at the Interior Department Auditorium, Friday, December 16, Mr. Coyle of the International Nickel Company spoke on "High Strength Cast Iron". Mr. Coyle is one of the prophets of the new revival in the scientific study of cast iron. Unlike some of the other experimenters he has confined himself to improvements which may be readily applied in the every-day foundry, always keeping in mind the question of costs. The successful results he has been able to get are of decided interest.

Mr. Coyle showed micrographs of the high-strength cast iron illustrating the grain refinement produced by about 2 per cent nickel. This cast iron has

a tensile strength of 65,000 pounds per square inch, and the compressive strength is three times that. It also has a well-defined yield point, about 10,000 pounds per square inch below the tensile strength. It has a high Brinell hardness but is readily machinable. It has good wear resistance, shows less growth than ordinary iron, and holds its strength up to temperatures of 1200 degrees Fahr. Attempts to improve the properties by heat treatment do not seem to have been very successful, but quenching from 1500 degrees Fahr. and tempering at 600 degrees Fahr. increased the strength somewhat. The iron is made in the cupola, large proportions of steel scrap being used. A temperature of about 2800 degrees Fahr. is desirable. The metal should be tapped shortly after melting to prevent absorption of too much carbon, as a rule about 15 minutes after molten metal begins to collect, or until about 1000 pounds have collected in a 36-foot cupola. The alloying is done in the ladle, which is preheated to prevent the cold alloying additions from unduly lowering the temperature. Ferro-silicon is added up to a composition of 0.80-0.50 per cent silicon for 2.5-3.25 carbon content iron respectively. Some ferromanganese is added as a deoxidizer; about 2 per cent nickel is the chief addition. The high strength can be obtained with silicon alone, but this causes too much shrinkage which does not occur with nickel. *Samuel Epstein.*

WORCESTER CHAPTER

The Worcester Chapter held its fourth regular meeting at Rebboli's Restaurant in Worcester on Dec. 9. The meeting was attended by 50 members who enjoyed a dinner served at 6:30 p. m., as a preliminary to the business of the evening. There being no Chapter business to be transacted, Chairman Bigelow announced a Question Meeting for the January assembly, and proceeded at once to introduce Dr. George L. Kelley, of Philadelphia, metallurgist with Edward G. Budd Mfg. Co., of Philadelphia, who gave a most interesting talk on sheet steel stamping. The speaker made three divisions of his talk as automobile steel, the testing of automobile steel, and difficulties encountered in the use of automobile steel, all from the laboratory point of view. The manufacture of automobile steel was interestingly outlined from the hot rolling of .10 carbon, .40 manganese slabs to sheet bars, through the subsequent operations of normalizing at 1800 degrees Fahr. to 2000 degrees Fahr., pickling, cold rolling, annealing, and a final annealing operation at 1050 degrees Fahr. to 1100 degrees Fahr., made in special boxes of 30,000 pounds capacity. In spite of the small amount of cold work (rolling) received by the material, this last annealing operation was successful because a large part of the hot rolling, finished at temperatures from 900-1000 degrees Fahr. was really cold work in its nature. A superficial roughness is purposely produced on the plates on the roughing rolls to prevent their adherence during subsequent annealing operations. The treatment of materials as to annealing was made difficult by varieties of size combinations demanded for the production of bodies. Automobile manufacturers' demands as to uniformity of gage, smoothness of surface, and excellence of drawing qualities made great care in the processing of the materials necessary.

Following the talk, several interesting slides of microstructure at different cold-work points were shown. Last on the program were two reels of moving pictures showing various operations in the Budd factory. They were well worth seeing. *R. A. Johnson.*

Chairman, Mr. Bigelow, opened the Worcester chapter's fifth monthly meeting with an appeal to all members to help sustain the chapter's present rate of growth. Mr. Bigelow enlarged upon the dual possibilities of the A. S. S. T. chapter meetings as mediums of exchange for ideas and helpful experience and as a means of providing a close bond of fellowship and material interest among the men of the profession. A question meeting had been arranged and "Ask Me Another" was to be the spirit of the evening. Mr. Bigelow turned the meeting over to the good management of G. A. Copeland, superintendent of the Winslow Skate Co., who read off the questions sent in by members and for which picked men had prepared answers. These questions had been lined up and answered:

I. Can High Speed Steel be Hardened by Heating in Charcoal to 1700 degrees Fahr. Quenching in oil and Tempering to 1100 degrees Fahr.? Answered by Lawrence Greenman, of the Greenman Steel Treating Co.

II. Carburizers. How Much Can We Depend Upon them for Uniformity? Answered by S. F. Brown, Whitinsville Spinning Ring Co.

III. Rust Preventions for Iron and Steel Parts. Answered by A. N. Hook, of E. F. Houghton & Co.

IV. What Late Developments are there in Electric Furnaces for Tool Hardening in Regard to Circulation of Air and High Tempertures? Answered by E. D. Learned, of the Worcester Electric Light Co.

V. Nitrodizing Process. By Mr. Grotty, Crompton and Knowles Loom Works.

VI. What Takes Place when you Roll a Drawn Steel Cold? Why Does the Elastic Limit Increase? Answered by Robert C. Jordan and C. Forse, of the Wickwire Spencer Steel Co.

VII. The Causes and Remedies for Excessive Cracking in Cast Iron? Answered by W. C. Searles, of the Leland-Gifford Co.

The question meeting, because of its success in providing a meeting of minds and in provoking free discussion from which much general benefit was derived, was declared a great success.

As a last move, the members voted to secure the Norton Company's film, "The Age of Speed" for an early meeting. *R. A. Johnson.*

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